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Fried et al.

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(45) **Date of Patent:** **Nov. 23, 2021**

(54) **CONFIGURABLE COMMUNICATION
SYSTEM USING STACKED ANTENNAS**

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(US)

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filed on Oct. 16, 2018.

(51) **Int. Cl.**

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H01Q 1/24 (2006.01)

(Continued)

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CPC **H01Q 21/10** (2013.01); **H01Q 1/246**
(2013.01); **H01Q 1/526** (2013.01); **H01Q**
21/0025 (2013.01); **H01Q 21/205** (2013.01)

(58) **Field of Classification Search**

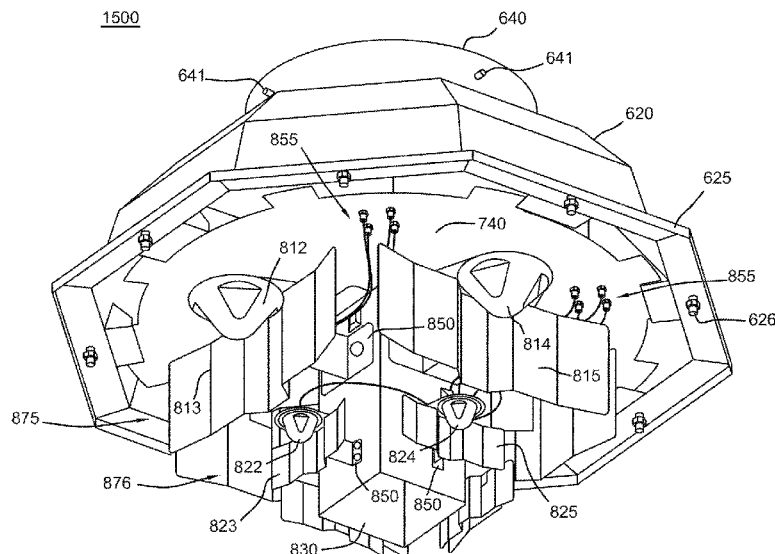
None

See application file for complete search history.

ABSTRACT

A configurable wireless communications module may include a first antenna layer having one or more antenna operating at a first wireless radio band; a second antenna layer having one or more antenna operating at a second wireless radio band; and a support structure for supporting the first antenna layer and the second antenna layer in a stacked configuration. The first antenna layer and/or the second antenna layer may be divided into sectors, with a directional antenna assigned to each sector, and with each directional antenna operating on a designated channel. Antenna layers may be individually accessed and removed/inserted for ease of maintenance and enhancement of function. An optional accessory module may support additional sensors and elements beyond antennas to allow for enhanced customization based on the intended application.

33 Claims, 22 Drawing Sheets



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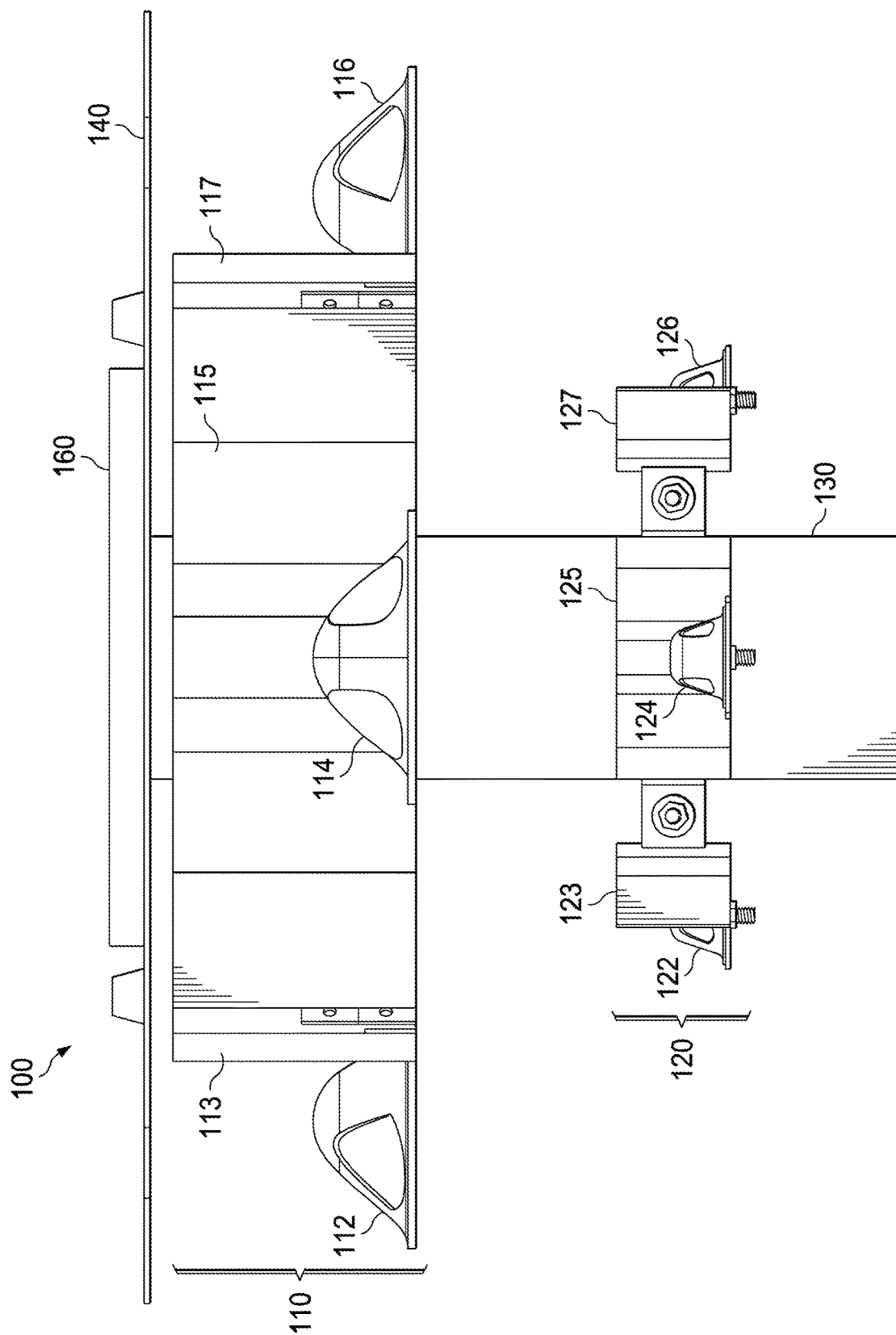


FIG. 1

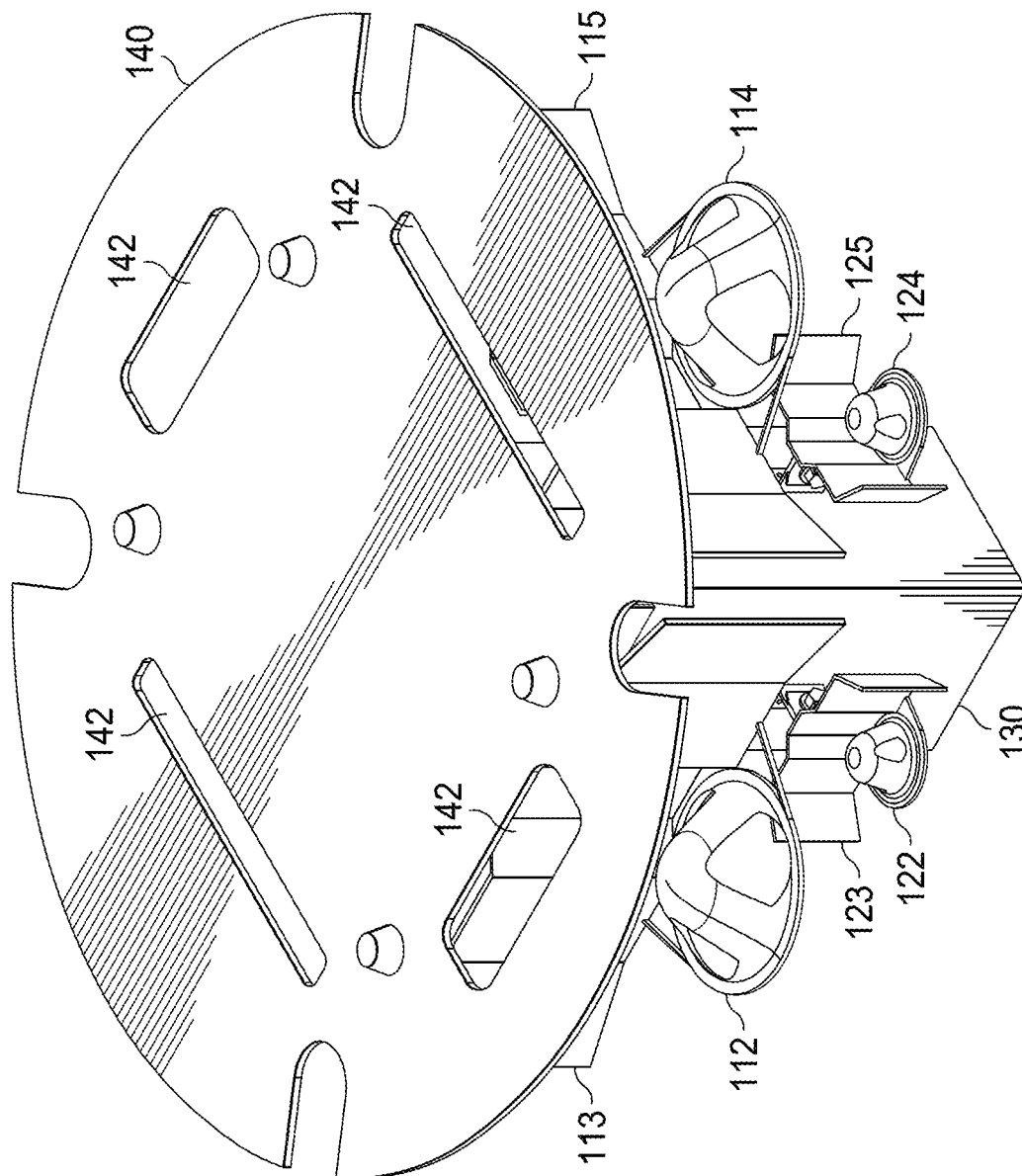


FIG. 2

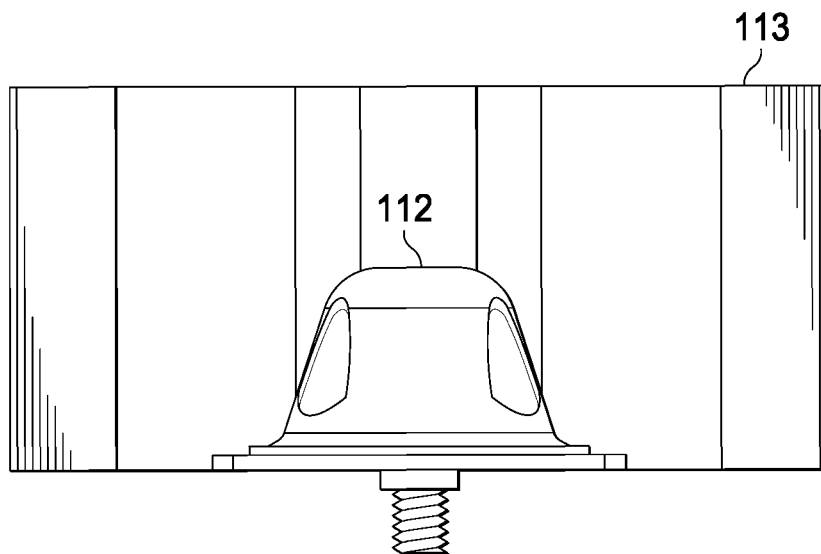


FIG. 3A

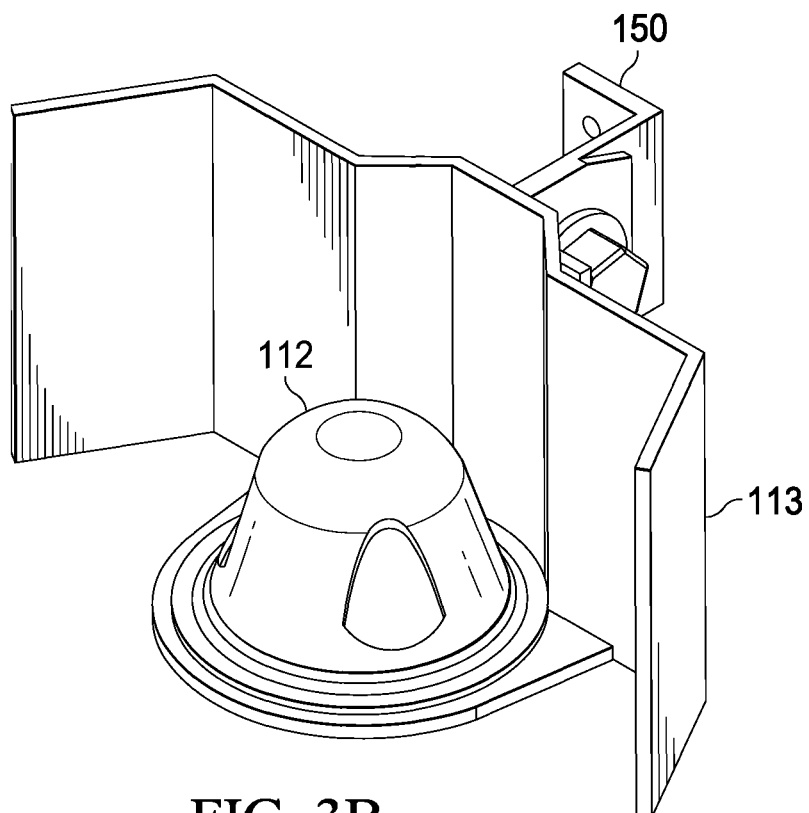


FIG. 3B

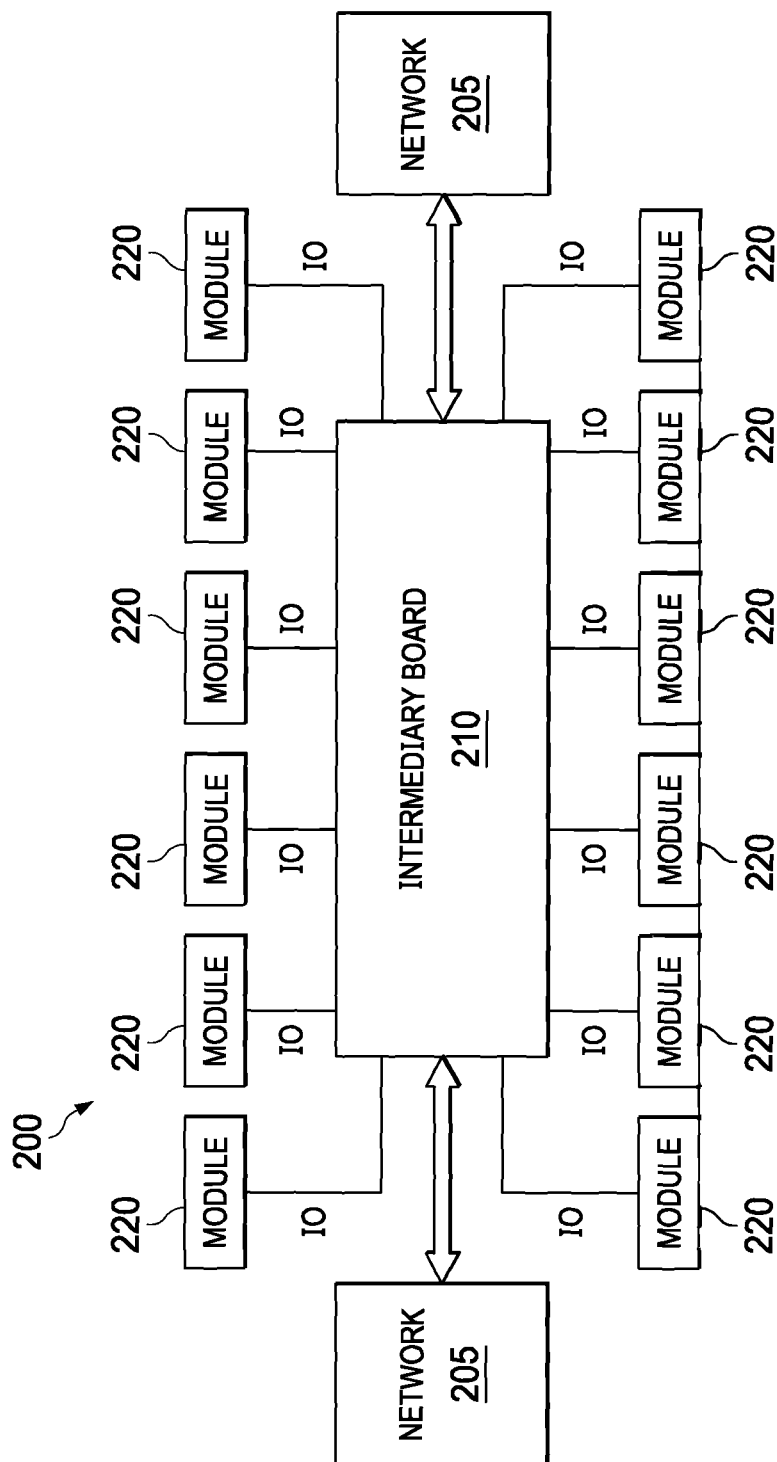


FIG. 4

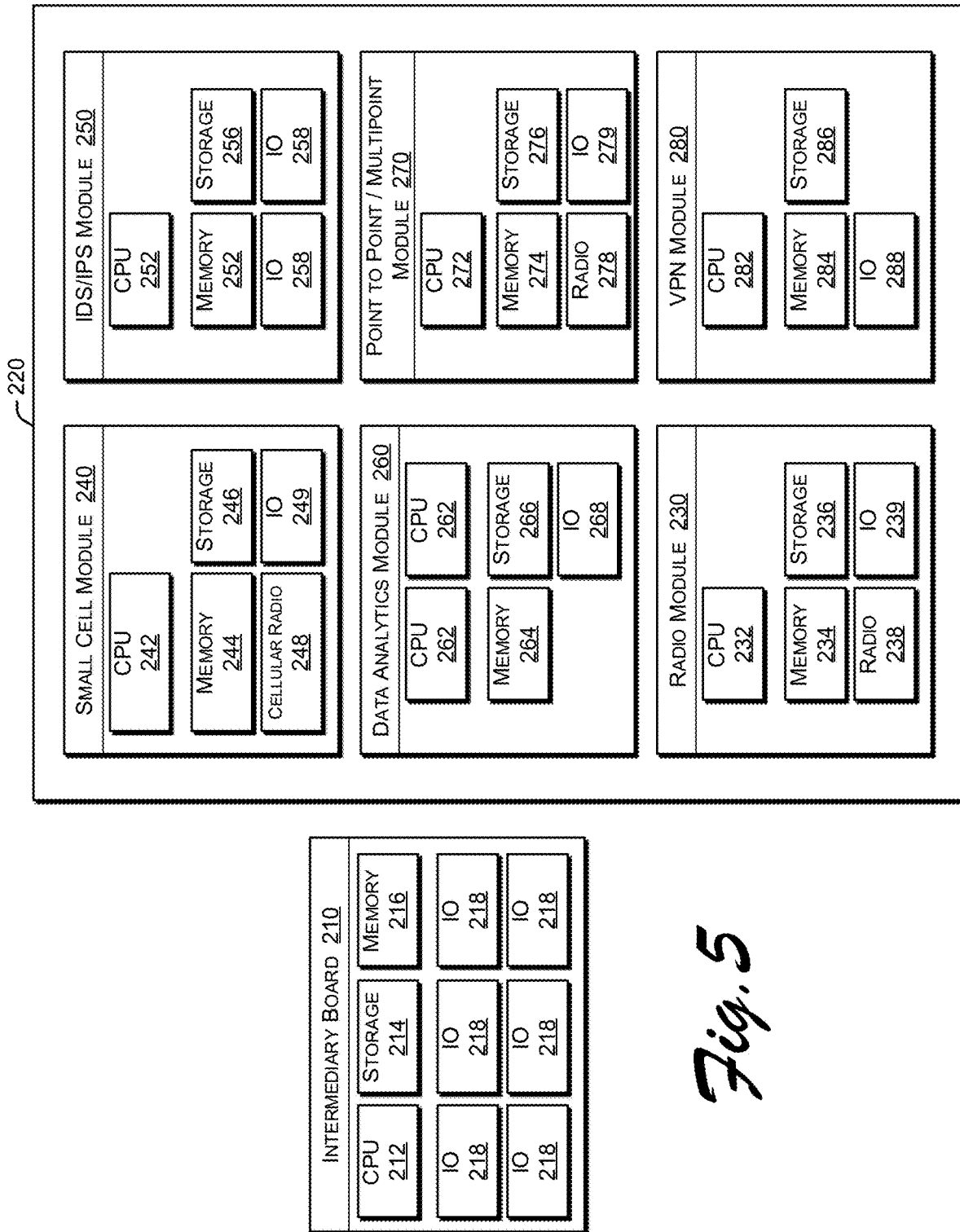
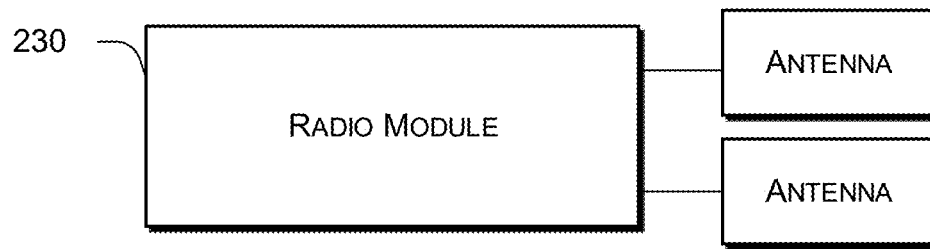


Fig. 5

*Fig. 6*

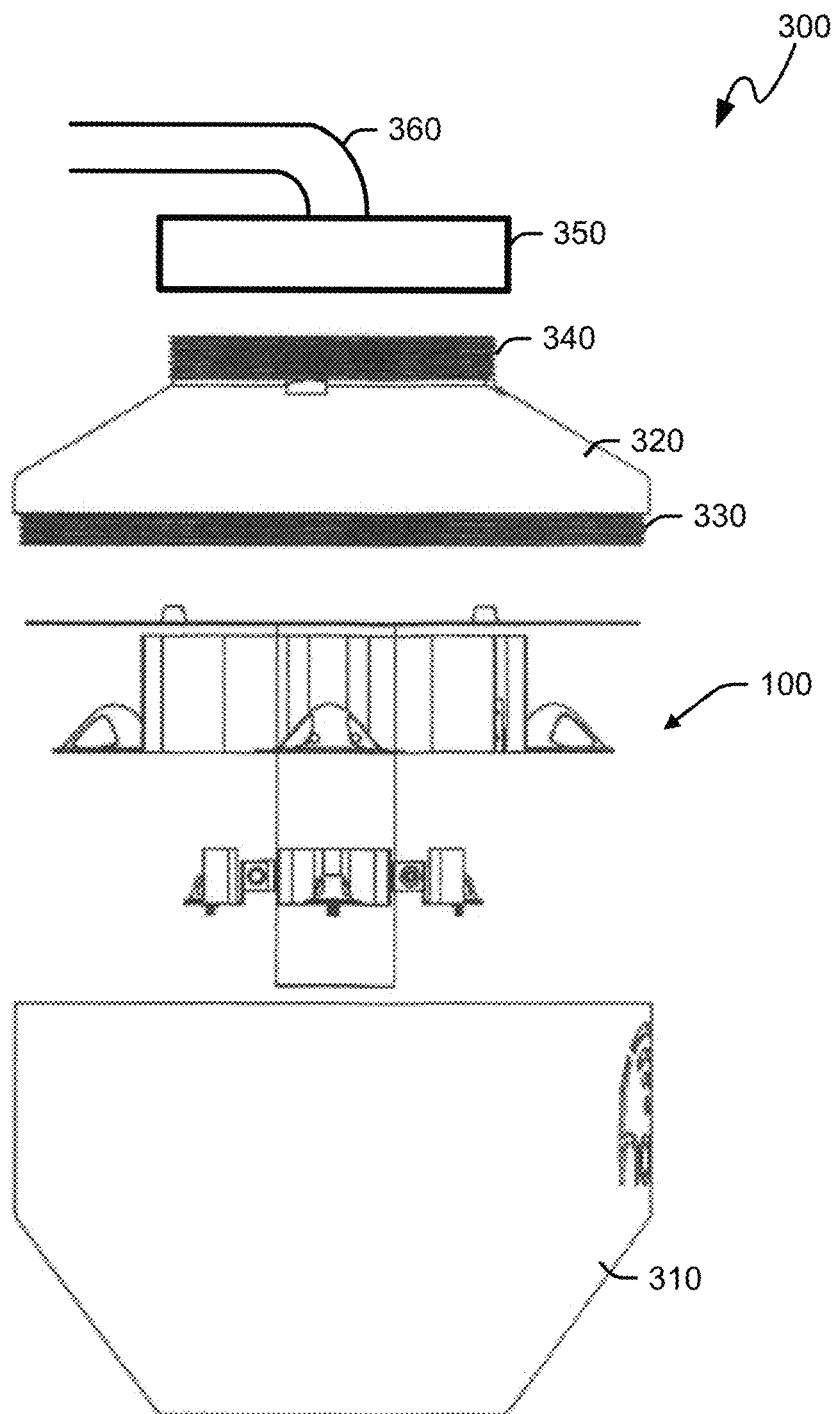


Fig. 7

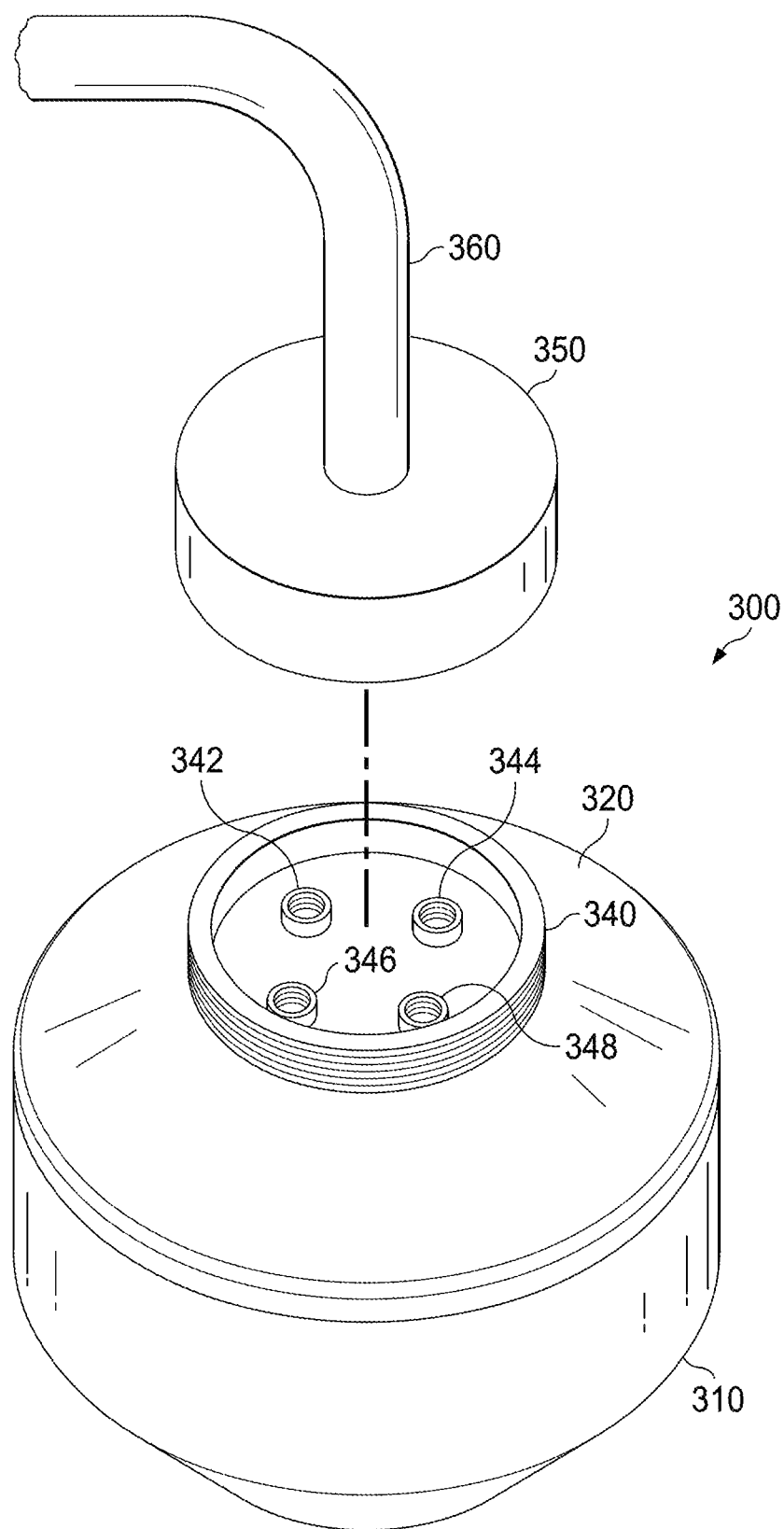


FIG. 8

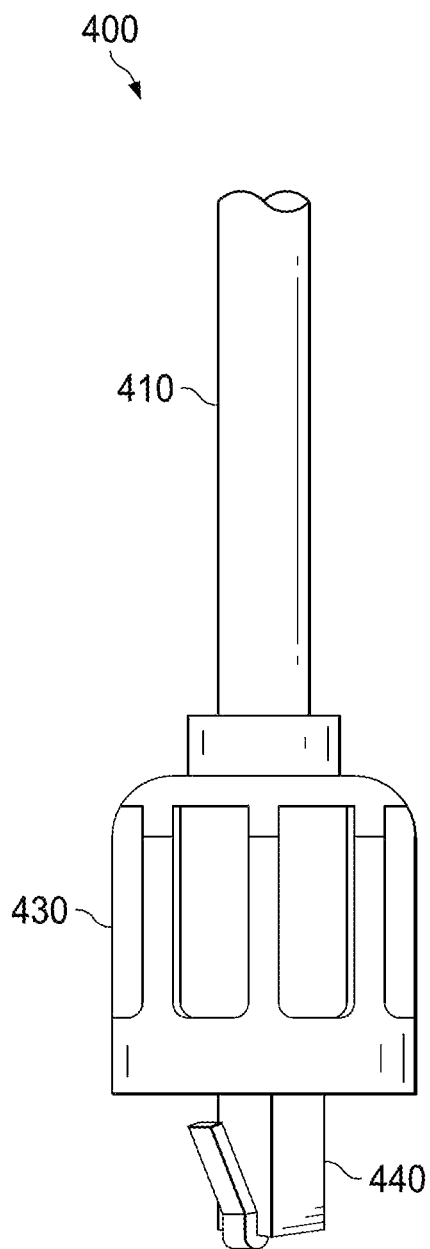


FIG. 9A

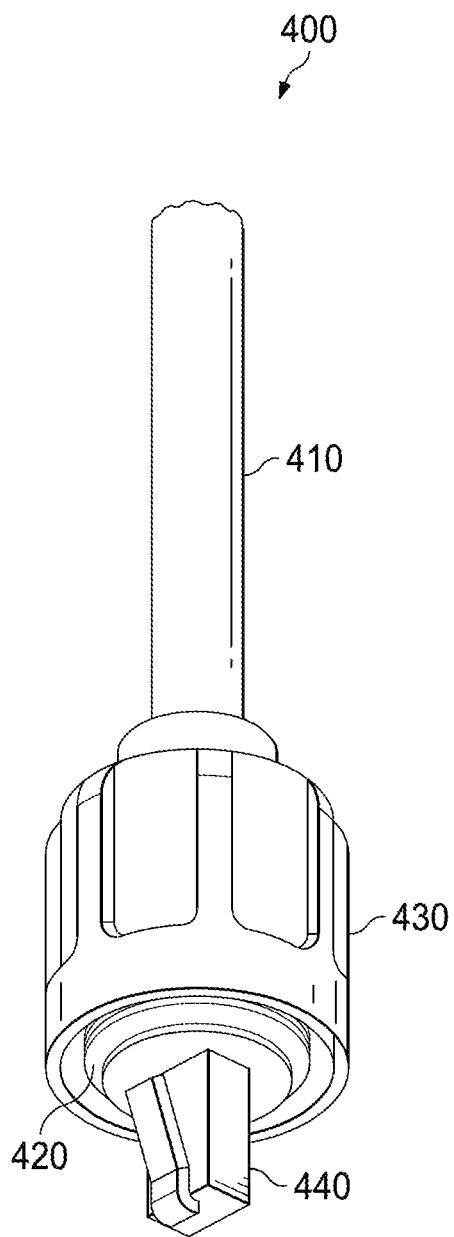
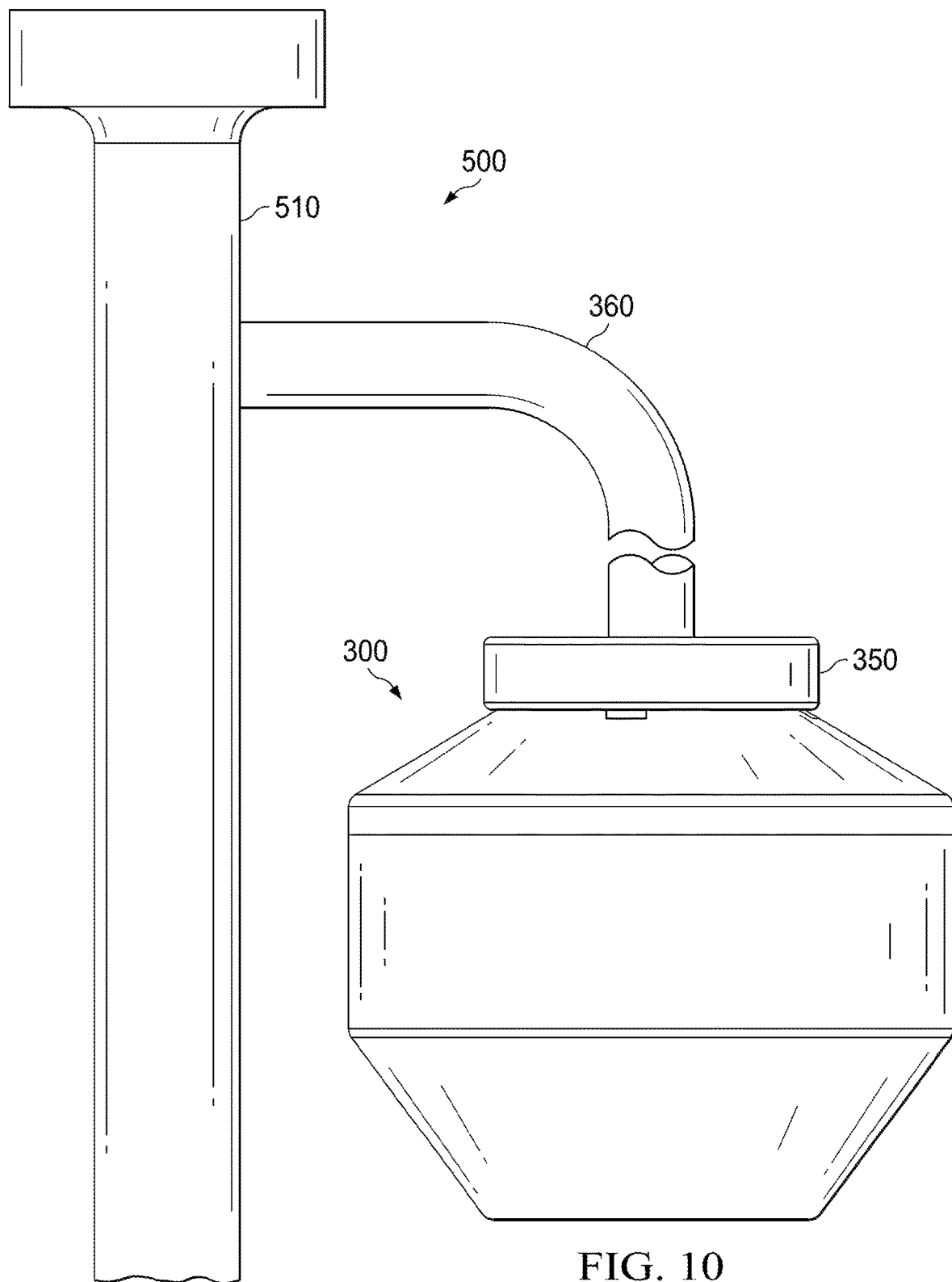
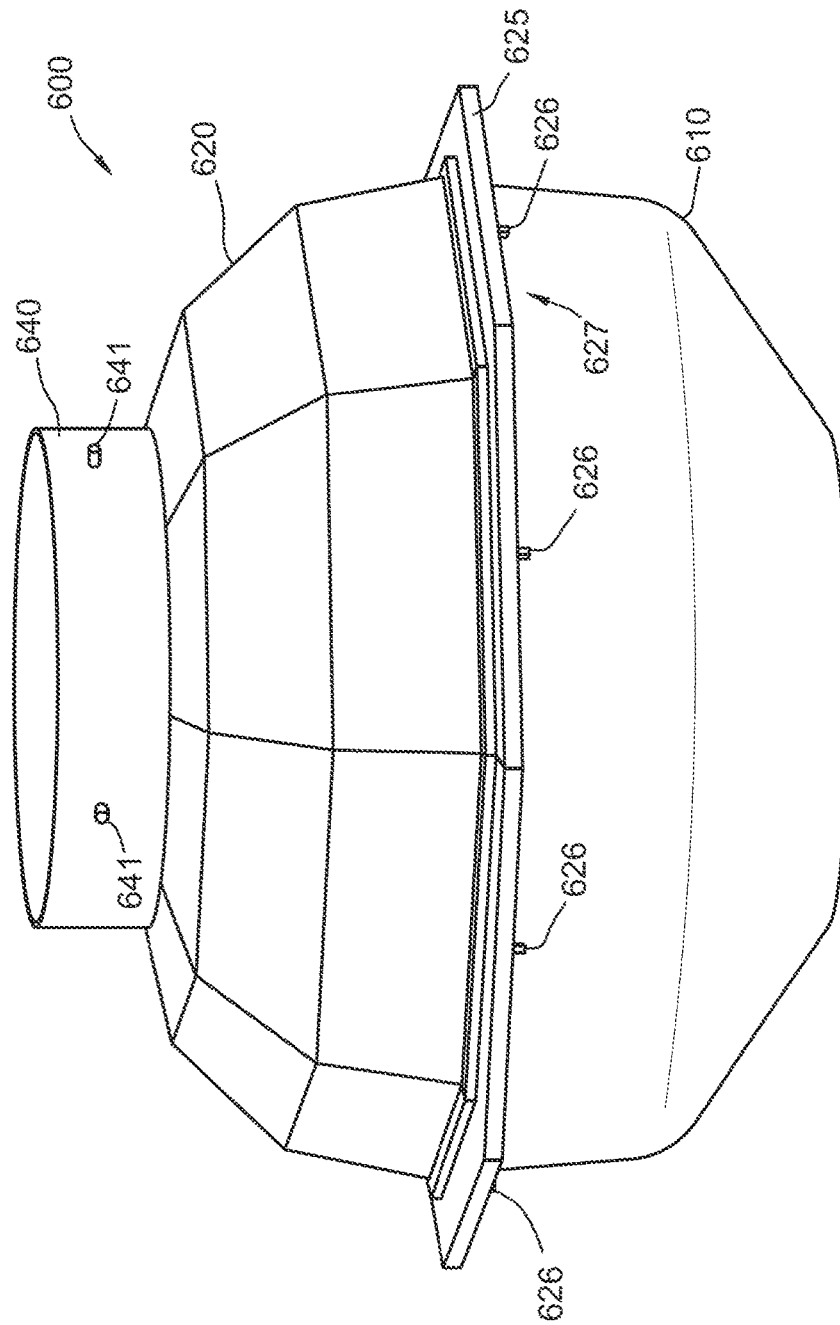


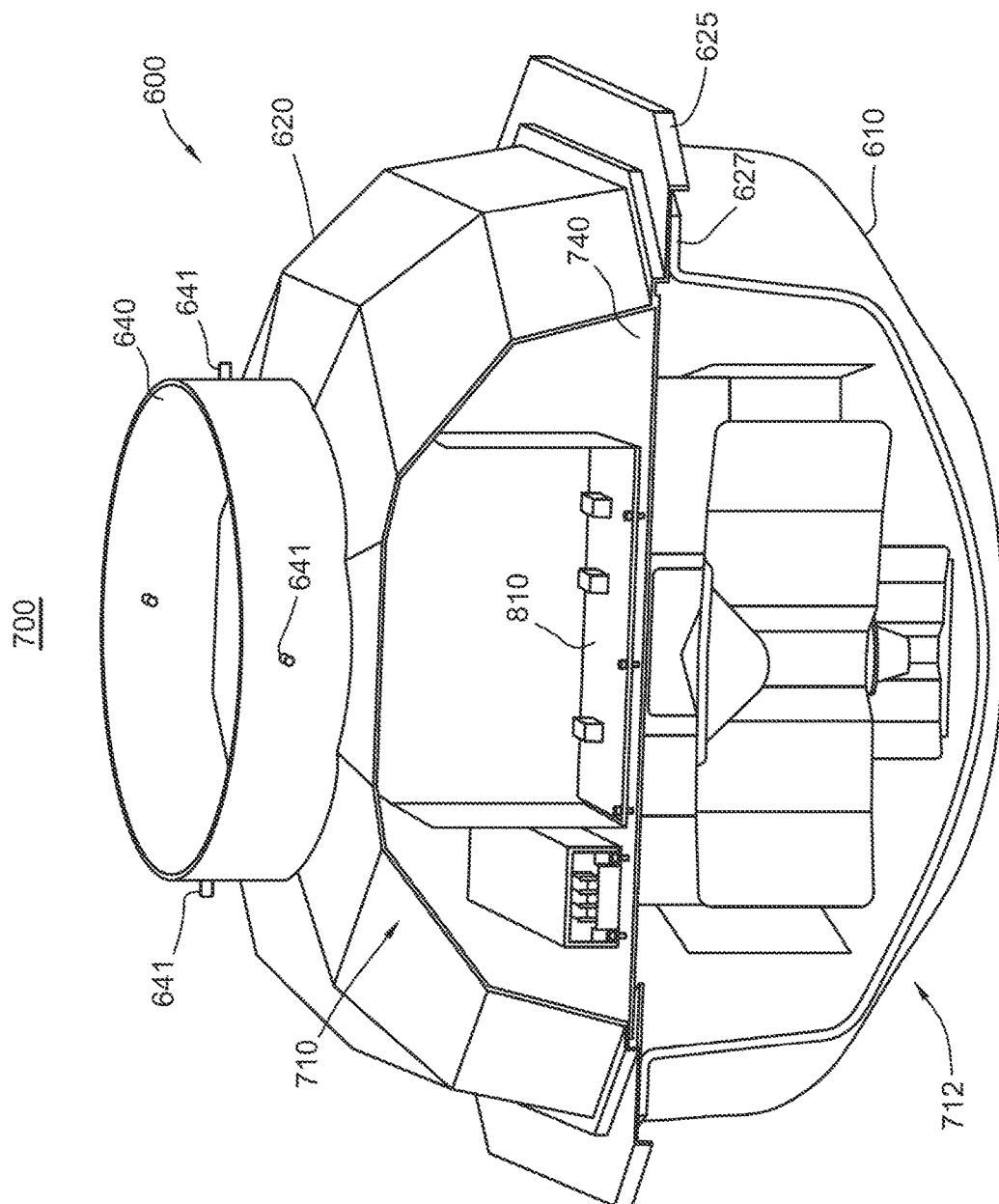
FIG. 9B



700



704 11



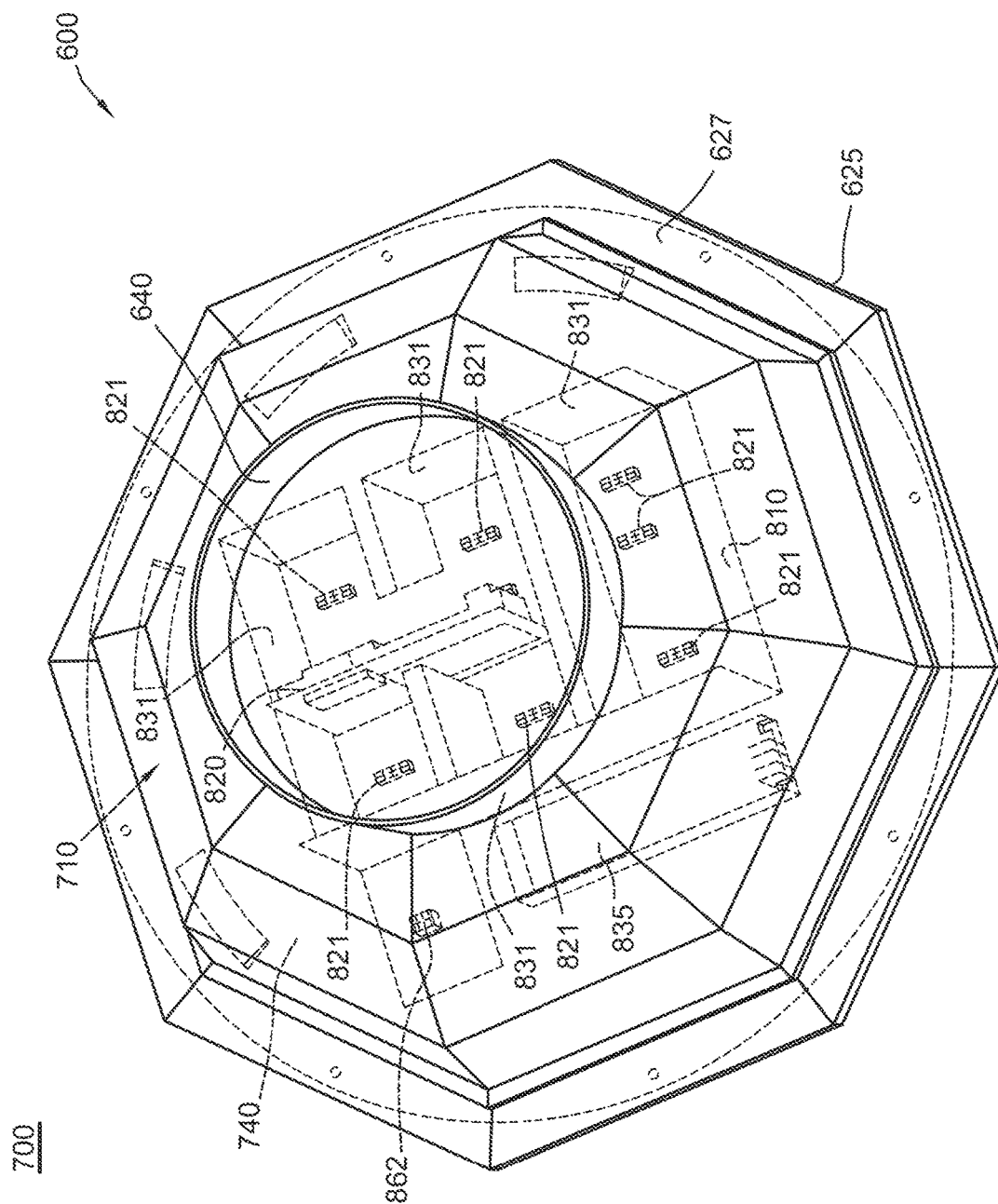


Fig. 13

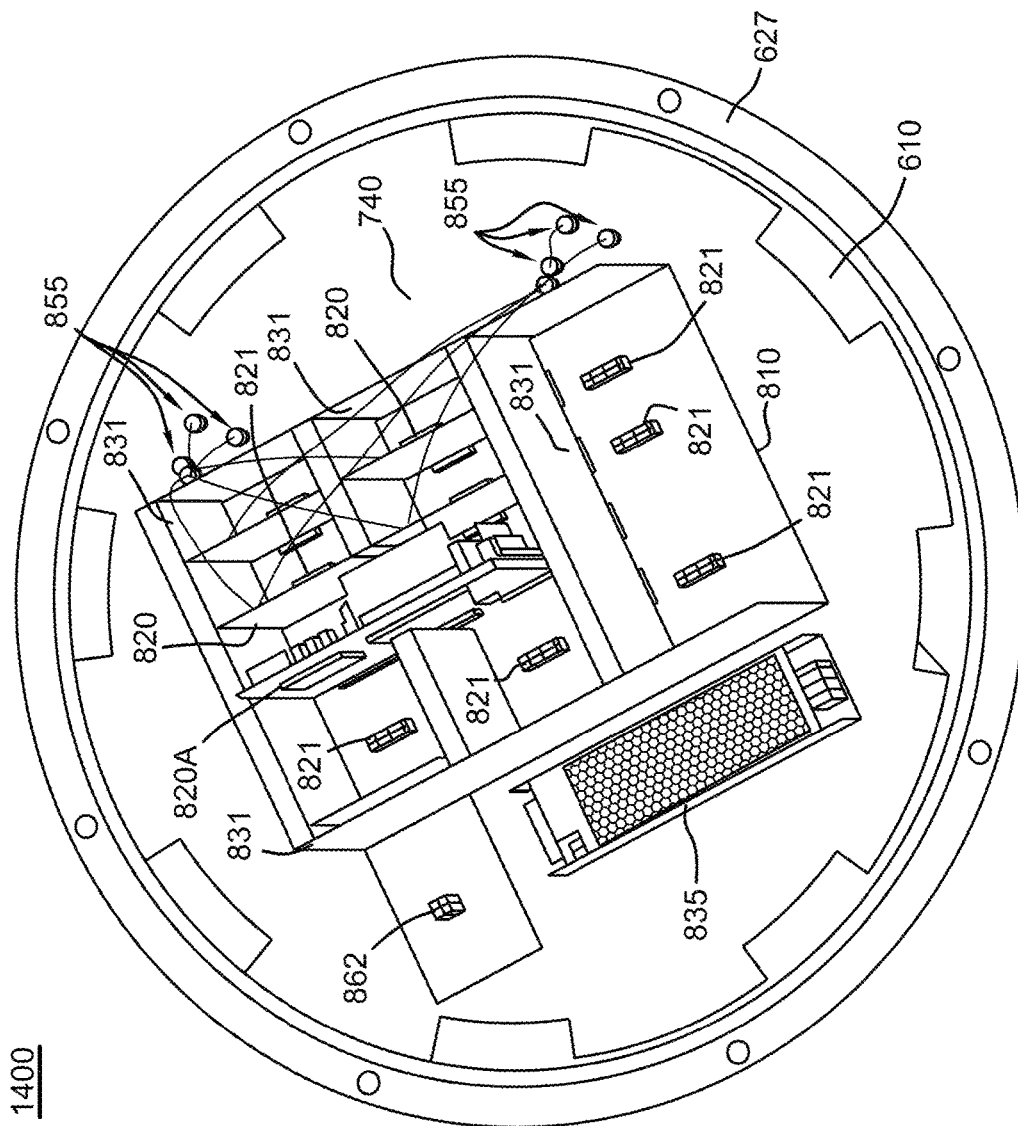


Fig. 14

1400

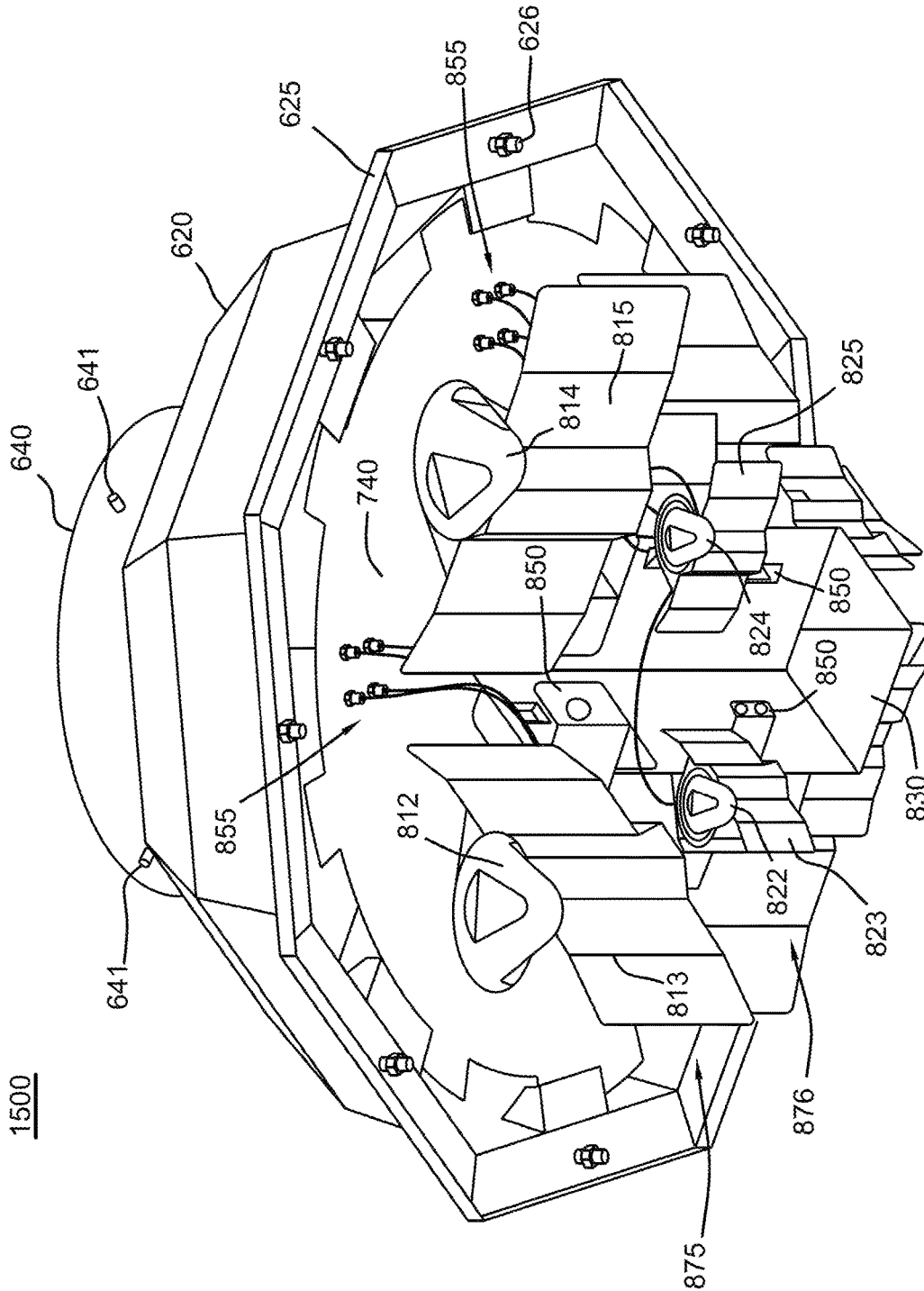


Fig. 15

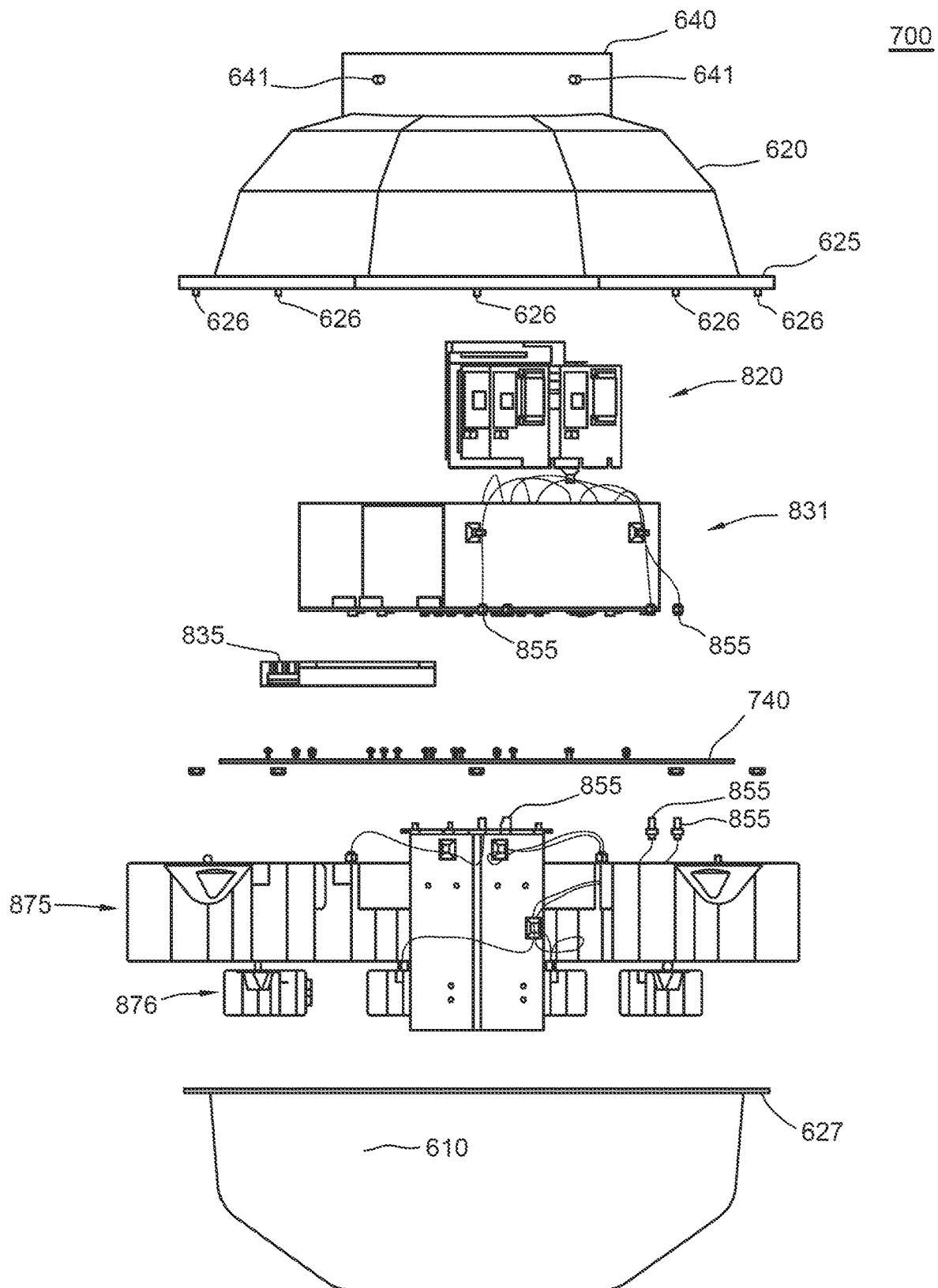


Fig. 16

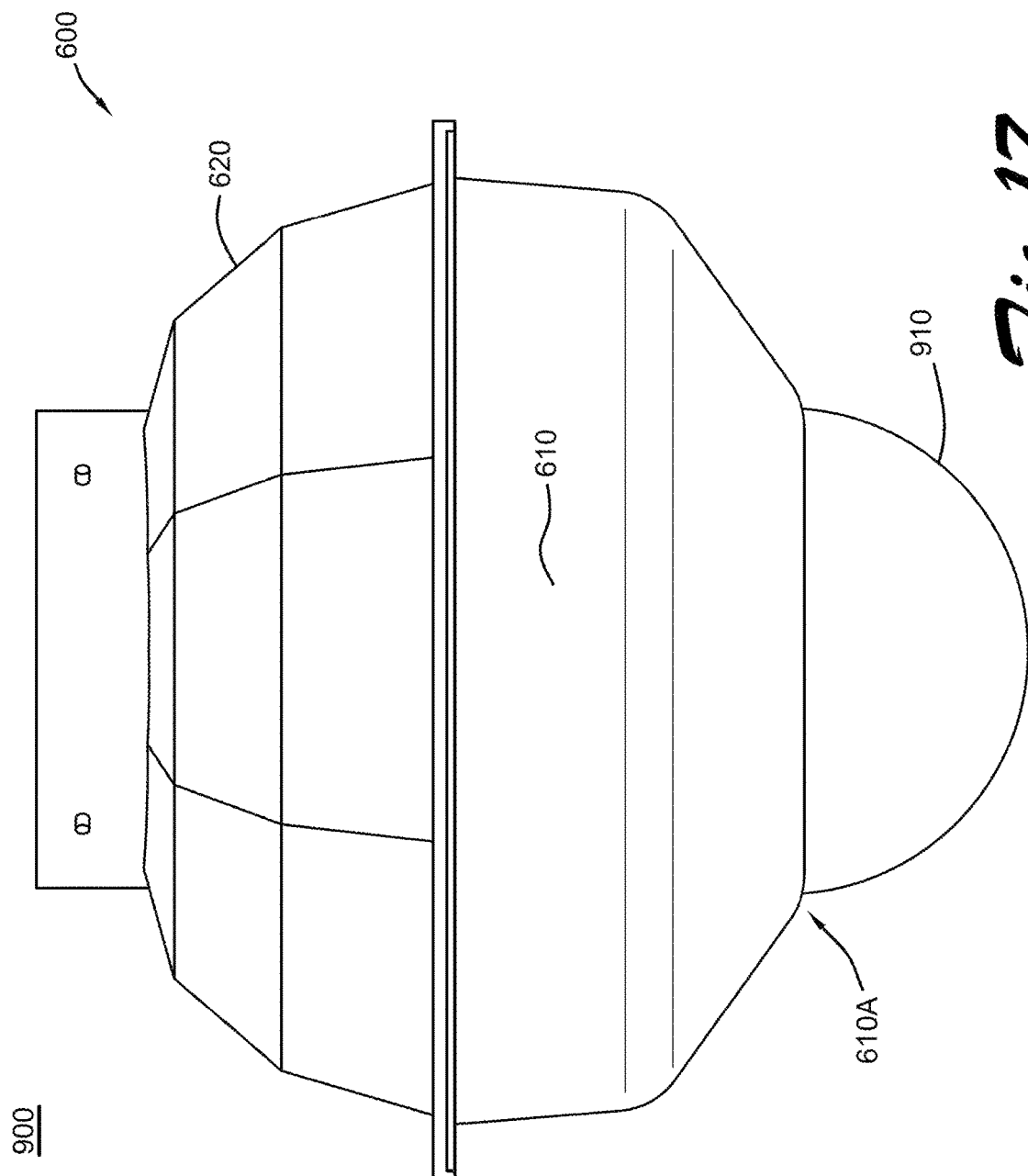


Fig. 17

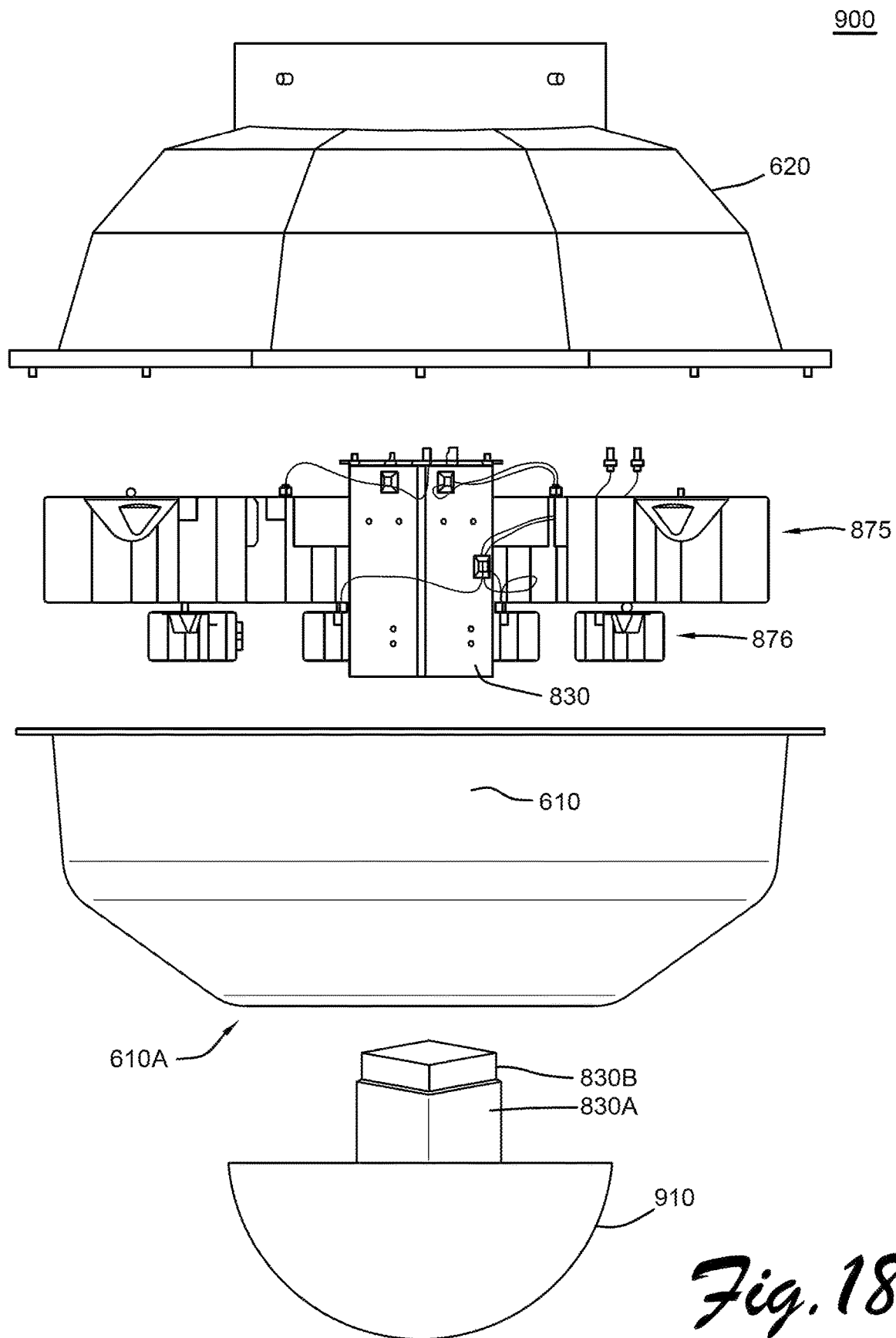


Fig. 18

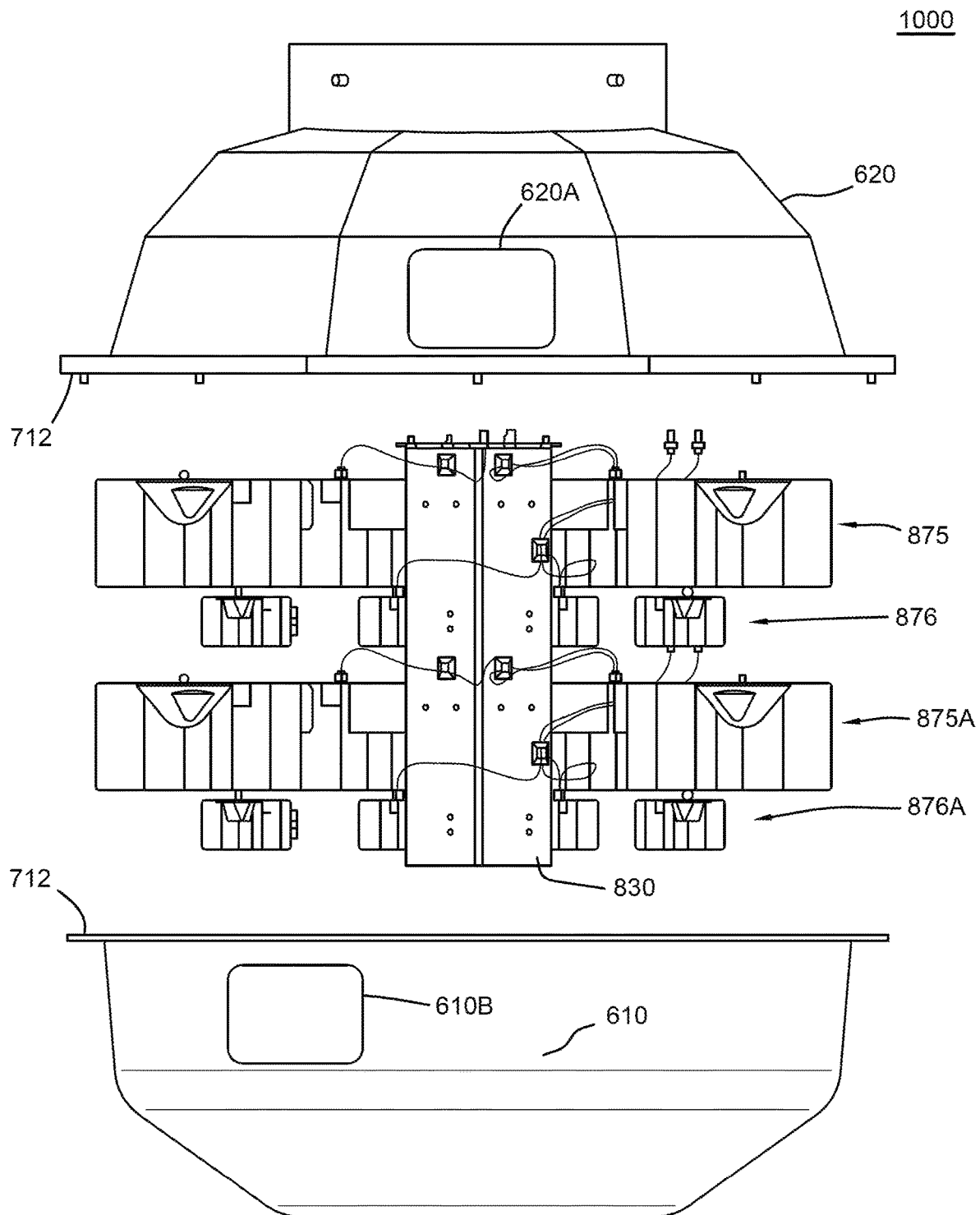


Fig. 19

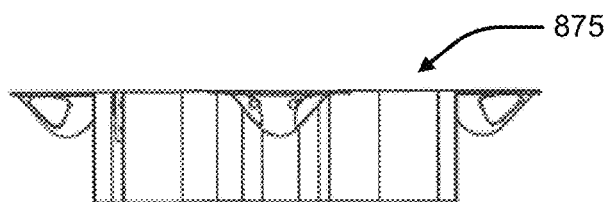


Fig. 20

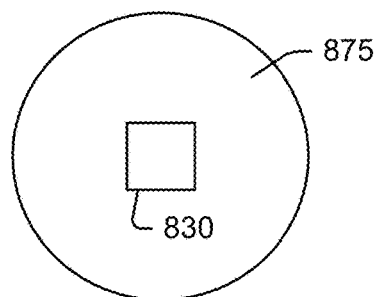


Fig. 21

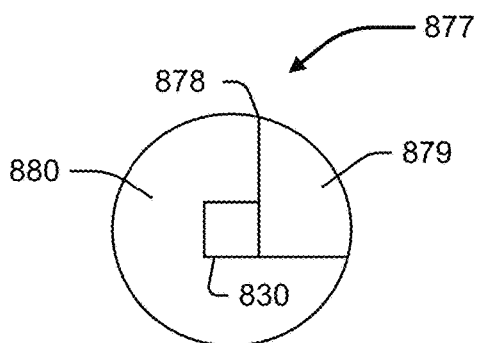


Fig. 22A

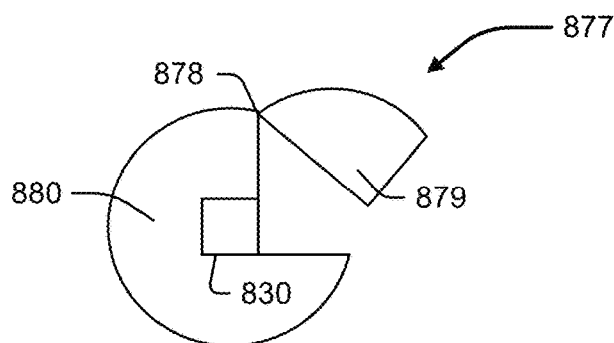


Fig. 22B

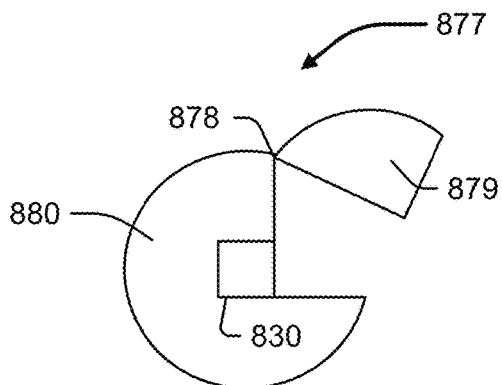


Fig. 22C

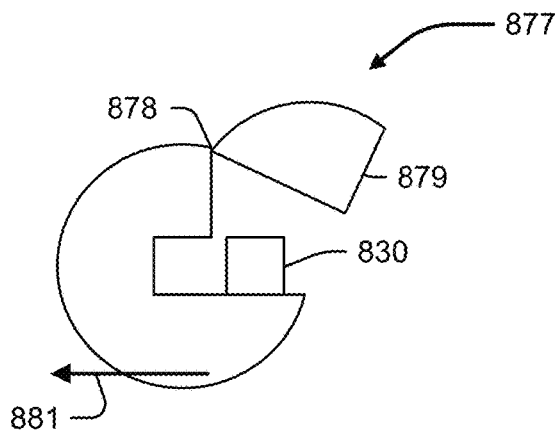


Fig. 22D

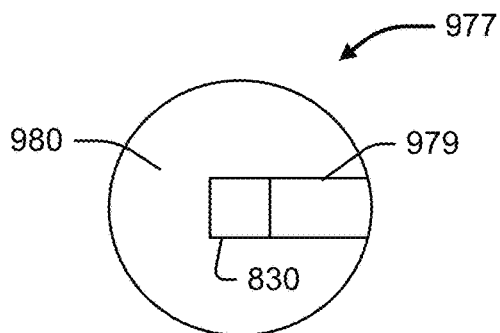


Fig. 23A

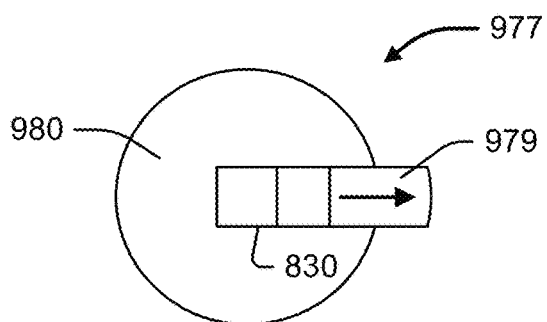


Fig. 23B

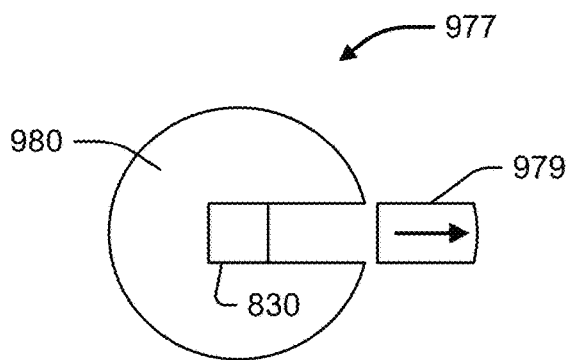


Fig. 23C

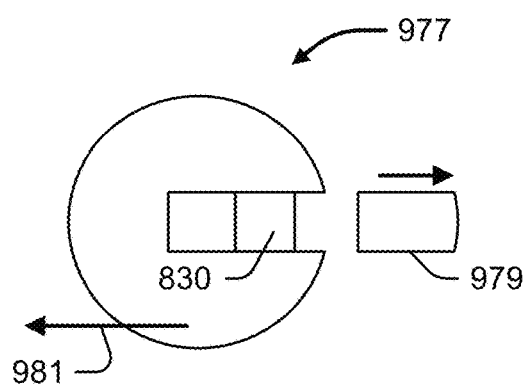


Fig. 23D

Fig. 24A

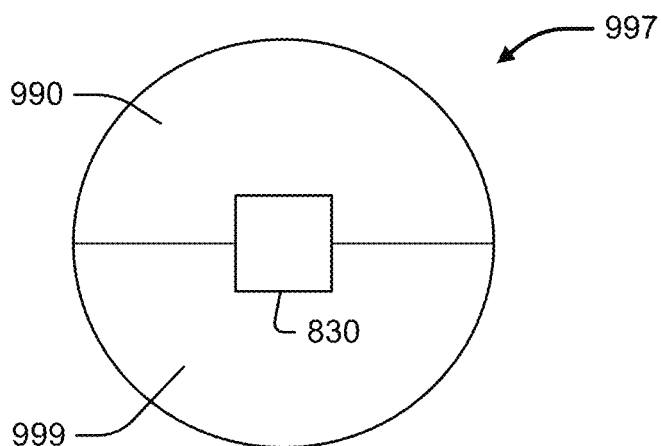


Fig. 24B

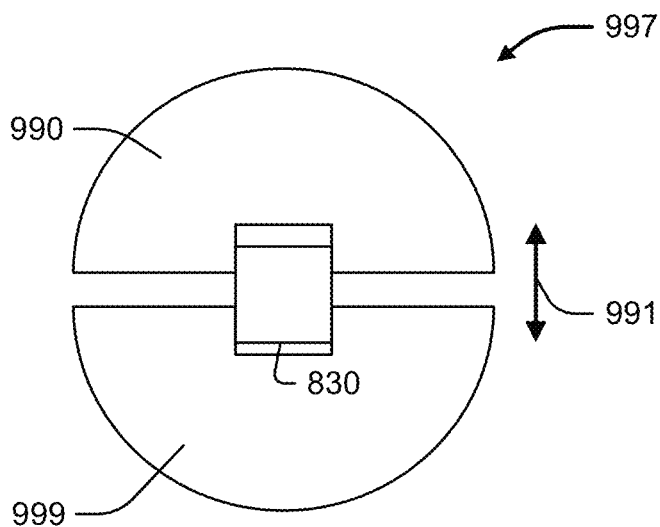
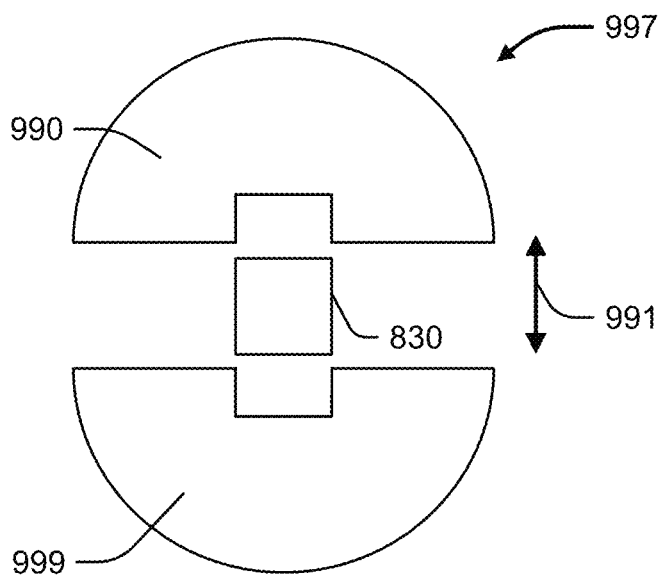


Fig. 24C



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CONFIGURABLE COMMUNICATION SYSTEM USING STACKED ANTENNAS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of and claims priority to U.S. non-provisional patent application Ser. No. 16/161,223 filed Oct. 16, 2018, titled, "Wireless Access Point Using Stacked Antennas," the disclosure of which is fully incorporated herein by reference for all purposes.

FIELD AND BACKGROUND OF THE INVENTION

Field of the Invention

The present disclosure relates to systems and methods for providing an improved wireless communications system with a plurality of antenna elements. More particularly, the present disclosure relates to a configurable wireless communications module using a stacked antenna array.

The present disclosure further relates to a modular circuit board for use in a telecommunications network, and particularly for use with a configurable communications module.

Background of the Invention

Wireless networking is becoming increasingly common, offering users the ability to move around from one site to another within a coverage area without having to operate from a wired port in a fixed location. A wireless access point (WAP), also known simply as "access point" (AP), is a networking hardware device on a wireless local area network (WLAN) that allows wireless-capable devices to connect to a wired network through a wireless standard, such as Wi-Fi.

Wi-Fi is a wireless communication scheme conforming to the 802.11 standards of The Institute of Electrical and Electronics Engineers, Inc. (IEEE). In the Wi-Fi scheme, two frequency bands are presently authorized by the Federal Communications Commission for wireless communication, namely the 2.4 GHz and 5.0 GHz wireless radio bands. Each of these wireless radio bands offers different capability. For example, the longer waves used by the 2.4 GHz band are better suited to longer ranges and improved transmission through walls, buildings, and other objects; however, the 2.4 GHz band is more congested and slower in speed. The shorter waves used by the 5 GHz band results in reduced range and diminished ability to penetrate walls and objects, but the 5 GHz band is less congested and transmits at higher speeds.

The 802.11 standard also provides for several distinct radio frequencies within each frequency band. Each distinct radio frequency—or channel—within a frequency band overlaps with adjacent channels on the same frequency band. Traditionally, a WAP is configured with one or more omnidirectional antennas, and the antennas transceivers on a channel within a frequency band. Devices on a channel must share the available bandwidth with all other devices on a channel. Allocation of finite bandwidth on a channel among numerous devices operating in the same geographic area is typically achieved with a multiplexing scheme such as orthogonal frequency division multiplexing ("OFDM").

Wireless access points and other such devices in a telecommunications network are further configured to electri-

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cally communicate with electronic circuit boards. In a conventional wireless access point, for example, the omnidirectional antennas of the wireless access point may be configured to electrically communicate with a single electronic circuit board. As a result, an update to any one of the antennas may necessitate replacement of the entire electronic circuit board. Similarly, the subsequent addition of one or more antennas to the conventional wireless access point may require the addition of one or more entirely-new electronic circuit boards.

SUMMARY OF THE INVENTION

The following technical disclosure is exemplary and explanatory only and is not necessarily restrictive of the invention as claimed.

The present disclosure relates to systems and methods for customizing and configuring a communications module using a stacked antenna array.

In some implementations, a configurable wireless access point may comprise a first antenna layer having one or more antenna operating at a first wireless radio band; a second antenna layer having one or more antenna operating at a second wireless radio band; and a support structure for supporting the first antenna layer and the second antenna layer in a stacked configuration. The first and/or second antenna layers may be divided into sectors, wherein if the first antenna layer is divided into sectors, the one or more antenna operating at the first wireless radio band comprises one or more directional antenna, each assigned to a different sector; and wherein if the second antenna layer is divided into sectors, the one or more antenna operating at the second wireless radio band comprises one or more directional antenna, each assigned to a different sector. The directional antenna assigned to each different sector operates on a designated channel, with directional antennas assigned to adjacent sectors operating on different designated channels to avoid signal interference.

In other implementations, a method of configuring a wireless access point may comprise mounting a first set of antennas operating at a first wireless radio band in a first layer around a support structure; and mounting a second set of antennas operating at a second wireless radio band in a second layer around the support structure, wherein the first layer and the second layer form a stacked configuration. The method may further comprise dividing at least one of said first layer and second layer into sectors; wherein if said first layer is divided into sectors, each antenna of said first set of antennas is assigned to a different sector; and wherein if said second layer is divided into sectors, each antenna of said second set of antennas is assigned to a different sector.

Embodiments of the present disclosure provide a configurable communications module comprising a plurality of antenna elements organized into a plurality of layers, each antenna element independently accessible and interchangeable within the communications module; a central support structure providing mechanical support for the plurality of layers; and a central controller module in electrical communication with the plurality of antenna elements; wherein the antenna elements within a layer of the plurality of layers operate within one assigned frequency band, each layer of the plurality of layers includes a shielding element to reduce interference with other layers of the plurality of layers, and each respective antenna element is respectively accessible for maintenance and replacement. The communications module may include a housing, wherein at least a portion of the exterior of the housing comprises environmentally pro-

tected and electrically transmissive material, for example, a material that is selected and designed to provide minimal signal attenuation of RF signals passing through the housing. The communications module may have any desired number of sections and enclosures, and in one embodiment includes an electronics section and an environmental component interface section. One or more partitions may be interposed between sections in the housing, such as between the electronics section and the environmental component interface section, and the partition may be configured to provide RF shielding between the sections (such as the electronics section and the environmental component interface section). In various embodiments, the partition includes electrical headers to allow electrical interconnect between modules disposed within the electronics section and components disposed within the environmental interface section.

In alternate embodiments, a housing of the present disclosure is removable to access and maintain at least one of the plurality of antenna elements and the central controller module. Antenna elements may be placed in electrical communication with the central controller through a plurality of cables passing within the central support structure, or alternatively, may be connected through direct or indirect wiring.

Antenna elements of the present disclosure may be configured to operate in any desired frequency band or plurality of frequency bands; in one embodiment, the antenna elements in at least one of the layers operate within a 2.4 GHz wireless radio band, or within a 5 GHz wireless radio band, or within a cellular telephony band such as an AMPS-related band, a 3G band a 4G-band, an LTE-band, a GSM-band or a 5G cellular telephony band.

In various embodiments, antenna elements may be arranged in layers, and further, respective layers may be configured to be installed on or removed from the central support structure as a layer unit. Further, in some embodiments, each respective layer may be independently removed from or installed within the communications module without removing other layers within the communications module. In some embodiments, within a layer, antenna elements may comprise a plurality of directional antenna elements oriented in respectively different directions, and in alternate implementations, may include a mix of directional and omnidirectional antenna elements. To assist in removability, in one aspect, respective antenna layers may comprise a C-Shaped layout with a hinged closure.

In one aspect, a central controller module comprises a plurality of radio modules respectively electrically connected to the plurality of antenna elements, and may further be interchanged without replacing the central controller module. The communications module also may include an interface from the antenna elements to an external communications network, and a connection to the external communication network may be implemented via any desired protocols and connections such as one or more of a fiber-based connection, a wired connection, and optical connection a cellular backhaul connection or a microwave link. The communications module of the present invention may comprise a variety of communication devices, including one or more of a Bluetooth transceiver and an RFID transceiver. Further, the communications module may further comprise one or more of: a fixed camera, a remotely controllable camera, one or more laser transmitters; one or more laser receivers; one or more laser transceivers; an infrared module; a smoke detector; a carbon dioxide detector; a carbon monoxide detector; an ozone detector; a particulate detector; a microphone; a speaker; an optical communications mod-

ule; a seismic sensor; a pollution sensing module; a gunshot detector; a lighting apparatus; a weather sensor; an avalanche detector; a tornado warning detector; a wind speed and direction sensor; a traffic sensor; a wireless charging transmitter/receiver/transceiver; a cellular repeater; a point-of-sale (POS) terminal; and a battery; further, any of these components may be installed anywhere on or within the communications module, such as within an accessory module mounted to a housing or a support structure of the communications module.

Antenna elements utilized in aspects of the present disclosure may comprise any desired types of elements such as an omnidirectional antenna element, and antenna elements may comprise a plurality of band transmission cores providing operation within a plurality of operating frequencies. In various embodiments, to ease re-configuration and/or maintenance of the communication module, each antenna element may be interchanged through a socketed connection to the central support structure. Further, in various embodiments, a plurality of antenna elements within a layer operate within a plurality of assigned frequency bands.

Antennas may be placed within certain aspects of the invention in any desired location; for example, where the central controller module is disposed at a first end of the support structure, an omnidirectional antenna element is disposed at an opposite end of the support structure. A 5G cellular antenna element may be placed in any desired location, such as at the bottom of the support structure, the sides of the housing, on a surface of at top member or bottom member of the housing, or any desired location.

In yet another embodiment, a central support structure may be extended by one of: telescoping an internal extension element and mechanically mating an extension thereto.

In a further embodiment, a communications module of the present invention is configured to operate within one of: an urban environment; a rural environment; a building; an airport; a farm; a factory; and a recreation area; and in some embodiments, may further include a solar panel interface that may further be in electrical communication with a battery.

In yet another embodiment, a communications module of the present invention may be configured to monitor any number of factors such as one or more of a soil composition; crop health; animal location; animal health; watering and/or irrigation moisture; oil well pressure; oil well flow; stadium human movement and traffic; human facial recognition; pollution emissions; vehicular traffic flow; a weather condition in proximity to the communications module; a safety-related condition; a crime event; a fire event; and combinations thereof. The communications module provide additional processing capabilities that are useful in a number of venues such as stadiums, performance arenas, and the like; for example, in various embodiments, the communications module is further configured to process one of: point-of-sale (POS) transactions; orders for a product or service to be delivered to a person's assigned seat; instructions to guide a person to a designated location; a person's ticket idicia to grant access to a venue; data obtained from a scan of a QR code displayed by a person in proximity to the communications module; interactive advertising to a person in proximity to an interactive signage; reservation requests for use of a facility; data for use in augmented reality presented on a mobile device; and combinations thereof.

In one additional aspect, at least a portion of an exterior of the communications module may comprise a radome, and the radome may be configured to include an electrically thin

dielectric layer, a half-wave thick layer, a foam-core laminate layer, a C-sandwich laminate layer, or a combination thereof. Established specific design considerations for selection of radome composition, structure, and geometries may be utilized by those of skill in the relevant arts, and examples are provided, for instance, in the article, "A Fundamental and Technical Review of Radomes" by Lance Griffiths, Ph.D., MPDigests.com, May 2008, available at http://www.onrampcomm.com/new/AdFiles/MFG%20Galileo_May08%20MPD.pdf, the disclosure of which is fully incorporated herein for all purposes.

The details of one or more implementations are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the implementations will be apparent from the description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present invention may be derived by referring to the detailed description and claims when considered in connection with the following illustrative figures.

For a more complete understanding of this disclosure and its features, reference is now made to the following description, taken in conjunction with the accompanying drawings, in which:

FIG. 1 illustrates a plan view of a wireless access point having a stacked antenna configuration, according to the present disclosure;

FIG. 2 illustrates a perspective view of the wireless access point having a stacked antenna configuration of FIG. 1, according to the present disclosure;

FIG. 3A illustrates a plan view of a single sectored antenna that may be used in a stacked antenna array, according to the present disclosure;

FIG. 3B illustrates a perspective view of the single sectored antenna of FIG. 3A, according to the present disclosure;

FIG. 4 illustrates a block diagram of a modular circuit board that may be used in a wireless access point having a stacked antenna array, according to the present disclosure;

FIG. 5 illustrates a block diagram of representative modules of the modular circuit board of FIG. 4, according to the present disclosure;

FIG. 6 illustrates a block diagram of an implementation of a radio module of the representative modules of the modular circuit board of FIG. 5, according to the present disclosure;

FIG. 7 illustrates an exploded plan view of a housing for enclosing a stacked antenna array, according to the present disclosure;

FIG. 8 illustrates a perspective view of an assembled housing for enclosing a stacked antenna array, according to the present disclosure;

FIG. 9A illustrates a plan view of a cable mount, according to the present disclosure;

FIG. 9B illustrates a perspective view of the cable mount of FIG. 9A, according to the present disclosure; and

FIG. 10 illustrates an assembled housing coupled to a support column, according to the present disclosure.

FIG. 11 illustrates a side perspective view of an assembled housing of the present disclosure.

FIG. 12 illustrates a cutaway view of a communications module of the present disclosure.

FIG. 13 illustrates a top perspective view of a communications module of the present disclosure, with the top member in semi-transparent rendering.

FIG. 14 illustrates a top perspective view of a communications module of the present disclosure, with the top housing member removed.

FIG. 15 illustrates a bottom perspective view of an embodiment of the communications module of the present disclosure with the bottom housing member removed.

FIG. 16 illustrates a side exploded view of an embodiment of the communications module of the present disclosure.

FIG. 17 illustrates a side view of an embodiment of the communications module of the present disclosure, showing an attached accessory module.

FIG. 18 illustrates a side exploded view of the communications module that illustrated in FIG. 17.

FIG. 19 illustrates a side exploded view of a communications module of the present disclosure.

FIG. 20 illustrates a side view of an exemplary antenna layer of the present disclosure.

FIG. 21 illustrates top profile view of an antenna layer of the present disclosure depicted in proximity to a central support structure.

FIGS. 22A-22D illustrate a removable antenna layer embodiment of the present disclosure with a hinged section.

FIGS. 23A-23D illustrate an alternate removable antenna layer embodiment of the present disclosure with a removable section.

FIGS. 24A-24C illustrate a separable and removable antenna layer embodiment of the present disclosure.

Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

Although wireless access points and small cell systems are have been used for some time, the modular and scalable design of the present invention allows communications nodes to be easily augmented, modified, and serviced. More particularly, embodiments of the present invention empower government entities and enterprise organizations to customize a communications module to address particular challenges in the wireless communications space, to modify the modules as requirements change, and to maintain and improve the modules as needed. Through provision of plug-and-play functionality in the software and hardware sides of the platform, customization can be performed months, weeks, or days after purchase. Prior art systems, on the other hand, are usually a one-size-fits-all solution that are difficult, if not impossible, to retrofit after purchase. For one particular example, if a stadium decides that intrusion prevention needs to be enhanced, using embodiments of the present inventions they can add a module to provide the desired functionality, or even swap out modules of lesser importance.

Applications of aspects of the present invention are numerous. Smart Farming applications can utilize communications nodes of the present invention to monitor and control growing conditions to achieve the highest crop efficiency; animal tracking can be utilized to determine health, location, and identification of animals grazing in open pastures or their location in an extensive stable facility; monitoring and control of systems for offspring care to help control or monitor growing conditions of the offspring, among others. Embodiments of the present invention may be equipped with modules specific to the application, such as a plurality of water quality modules and pollution detection modules, and may forego unneeded elements such as a WiFi

or LTE module. Should wireless connectivity be required, such elements may be added to the communications module at any desired time.

Conventional wireless access points typically utilize one or more omnidirectional antennas which offer a 360-degree radiation pattern and operate at a singular radio band. Depending upon the implementation, such systems may include limitations on range of coverage, lack of system flexibility, and difficulties in managing system upgrades. Additionally, under conventional systems, migration to new wireless technologies may require a complete replacement of existing wireless access points.

Because Wi-Fi devices operate within a finite spectrum of available bandwidth, the overall performance of a wireless network will decrease as the number of devices and wireless access points within a geographic area increases. As consumers increasingly rely on mobile communications devices, the number of wireless access points in cities and other populated geographic areas will continue to increase. Accordingly, channel congestion will increase, thereby decreasing communications performance for all devices in an area. However, wireless communications performance may be improved when transceivers within a geographic area operate on non-overlapping channels. Performance may be further improved when transceivers operate on different channels from other transceivers within the same geographic area. As consumers increase mobility and demand greater flexibility, the configurable wireless access point described in the present disclosure offers varied options for Wi-Fi connectivity and allows for continued improvement in wireless technology.

Moreover, the one or more omnidirectional antennas utilized by a conventional wireless access point is typically configured to electrically communicate with a single electronic circuit board. Thus, an update to or replacement of one or more antennas may require replacement of the entire electronic circuit board. Likewise, the later addition of one or more antennas to the wireless access point may require the addition of new, corresponding electronic circuit boards. These configurations not only impose physical burdens on the system (i.e., physical space, additional bus structures, wiring, etc.), but also reduce the ease and flexibility desired in a field that is constantly advancing. The modular circuit board described in the present disclosure allows for the configuration of a plurality of independent circuit modules, each of which is independently configurable and interchangeable, thereby minimizing impact to the system as a whole.

Embodiments of the present disclosure are directed to a configurable wireless access point having a stacked antenna array and a modular circuit board for use with the configurable wireless access point. In an implementation, the stacked antenna array may comprise one or more stacked layers of antennas, each layer of antennas directed to a different wireless radio band, and each antenna within each layer of antennas being sectorized and directional. As described in detail below, such arrangement increases range of wireless coverage, improves system flexibility, and allows for ease in system maintenance and upgrade.

Reference is made to FIGS. 1 and 2, which depict in plan view and perspective view, respectively, a wireless access point 100 having a stacked antenna configuration according to the present disclosure. Wireless access point 100 may comprise a first antenna layer 110 having one or more antenna 112, 114, 116 operating at a first wireless radio band. The first wireless radio band may comprise, e.g., a 2.4 GHz wireless radio band, a 5 GHz wireless radio band, or other

wireless frequency known, used, developed, or to be standardized in the art. The one or more antenna 112, 114, 116 of the first antenna layer 110 may be supported by support structure 130. In an implementation, support structure 130 may comprise a metal support, such as a square pole, round pole, or other similar structure to which the one or more antenna 112, 114, 116 may be affixed. Preferred embodiments shown in FIGS. 1, 2, 7, 12, 15, 16, and 18 include two layers having 4 antenna elements each respectively disposed in four 90-degree quadrants, and in one embodiment, a lower layer operates within a 5 GHz band and an upper layer of antenna elements operates in a 2.4 GHz band. In various embodiments, a radio module (FIGS. 5 and 6, 230) may be connected to and operate one or two antenna elements. Although four antenna elements have been illustrated per layer, those of skill in the relevant arts understand that fewer or more directional antenna elements may be utilized per layer, such as 1 element, 2 elements, 6 elements, 8 elements, or any other desired number.

With continued reference to FIGS. 1 and 2, wireless access point 100 may further comprise a second antenna layer 120 having one or more antenna 122, 124, 126 operating at a second wireless radio band. The second wireless radio band may comprise a wireless frequency different from the first wireless radio band. For example, if the first wireless radio band is designated to a 2.4 GHz wireless frequency, then the second wireless radio band may be designated to a 5 GHz wireless frequency or any other wireless frequency known, used, developed, or to be standardized in the art. The one or more antenna 122, 124, 126 of the second antenna layer 120 may also be supported by support structure 130.

Importantly, the first antenna layer 110 operating at a first wireless radio band and the second antenna layer 120 operating at a second wireless radio band may be arranged in a stacked configuration, i.e., with a first antenna layer 110 stacked atop a second antenna layer 120 and supported by support structure 130, as depicted in FIGS. 1 and 2. One benefit of this configuration is the ease with which the wireless access point 100 may be modified, customized, or upgraded without removing and/or rebuilding the entire configuration. For example, as technology continues to improve, potential changes in the Wi-Fi standard (e.g., to a standard other than the 2.4 GHz or 5.0 GHz wireless frequencies) would not necessitate the removal or rebuilding of the entire wireless access point. Instead, outdated antennas and/or antenna layers may be replaced as needed.

While FIGS. 1 and 2 depict three antennas 112, 114, 116 at the first antenna layer 110 and three antennas 122, 124, 126 at the second antenna layer 120, the present disclosure is not limited to any particular number of antennas or any particular number of antenna layers. As described in detail below, additional antennas may be incorporated at each antenna layer to increase the capacity and directional distance of the wireless access point 100.

With continued reference to FIGS. 1 and 2, in an implementation, the first antenna layer 110 may be sectorized to divide up the first antenna layer 110 circumferentially (at least 360°) around the wireless access point 100, i.e., with each of the one or more antenna 112, 114, 116 assigned to a different sector 113, 115, 117. Likewise, the second antenna layer 120 may also be sectorized, with each of the one or more antenna 122, 124, 126 assigned to a different sector 123, 125, and 127. Sectorization of antennas at an antenna layer widens the coverage area of the network and therefore increases the number of clients that may be served by the wireless access point 100.

In an implementation, if the first antenna layer 110 is sectorized, the one or more antenna 112, 114, 116 in the first antenna layer 110 may comprise one or more directional antenna, each directional antenna assigned to a different sector in the first antenna layer 110. Similarly, if the second antenna layer 120 is sectorized, the one or more antenna 122, 124, 126 in the second antenna layer 120 may comprise one or more directional antenna, each directional antenna assigned to a different sector in the second antenna layer 120. Each of the one or more directional, sectorized antenna in the first and/or second antenna layer may operate at a designated channel, with adjacent sectors in a given antenna layer operating at different designated channels to reduce signal interference. Channels may be designated and assigned based on interference patterns. For example, channels 1, 6, and 11 may be non-overlapping channels deemed as having minimal interference. Thus, adjacent sectors in a given antenna layer may operate at a different one of channels 1, 6, or 11. By employing sectorized, directional antennas, the wireless access point 100 not only increases its capacity, but also increases its directional distance/range.

The one or more sectorized, directional antenna may operate in any number of configurations, including, e.g., 120°, 60°, or 30° configurations. In an implementation, a 120° configuration may comprise four sectorized, directional antennas arranged circumferentially (to cover at least 360° around the wireless access point 100) and equidistantly around the support structure 130 in the first and/or second antenna layers. This configuration ensures overlap in coverage between adjacent sectors, thereby avoiding gaps in the network. As a result, the Wi-Fi signal of a device of a user traveling between ranges of adjacent sectors may be handed off to the next antenna and thereby minimize signal drop-off.

In another implementation, a 60° configuration may comprise eight sectorized, directional antennas arranged around the support structure in the first and/or second antenna layers. In yet another implementation, a 30° configuration may comprise sixteen sectorized, directional antennas arranged around the support structure in the first and/or second antenna layers. Although 120°, 60°, and 30° configurations are described, the present disclosure is not limited to any particular configuration or to the use of any particular number of sectorized, directional antennas. Moreover, various configurations may be applied to various antenna layers.

Reference is now made to FIGS. 3A and 3B, which depict detailed plan and perspective views, respectively, of a sectorized antenna according to the present disclosure. While the antenna shown in FIGS. 3A and 3B is designated antenna 112, it may be any one of the antenna 112, 114, 116, 122, 124, 126 shown in FIGS. 1 and 2. Likewise while the sector shown in FIGS. 3A and 3B is designated sector 113 (corresponding to associated antenna 112), it may be any one of the sectors 113, 115, 117, 123, 125, 127 shown in FIGS. 1 and 2. Importantly, only one antenna may be assigned to each sector. Sector 113 may physically be coupled to support structure 130 via sector mount 150. Sector mount 150 may be removably attached to support structure 130 via screws, bolts, or any other connection means known in the art.

With further reference to the wireless access point 100 of FIGS. 1 and 2, a ground plate 140 may be layered atop the first antenna layer 110 and coupled to support structure 130. Ground plate 140 may serve as a grounding structure and may allow for the placement of one or more electronic circuit boards 160 thereupon. As shown in FIG. 2, ground plate 140 may be configured with slots 142 through which connection wires/cables from one or more electronic circuit

boards 160 may be guided for connection to the one or more antennas 112, 114, 116, 122, 124, 126 of the wireless access point 100. Each of the one or more electronic circuit boards 160 may be configured to electrically communicate with the one or more antennas 112, 114, 116, 122, 124, 126 of the first and/or second antenna layers 110, 120, and may include, e.g., a processor, a memory, storage, and other electronic components known in the art.

With reference now to FIG. 4, according to an implementation, the electronic circuit board for use with the wireless access point 100 may comprise a modular circuit board 200. Modular circuit board 200 may be mounted on ground plate 140 and may comprise a plurality of modules 220 (collectively numbered 220 in FIG. 4), each module operable as an independent and separate circuit board. In an implementation, each of the one or more modules of the plurality of modules 220 may be assigned to electrically communicate with a separate one of the one or more antennas 112, 114, 116, 122, 124, 126 of the first and second antenna layers 110, 120. In yet another implementation, certain modules of the plurality of modules 220 may be directed to other functionalities that advance the operation of the wireless access point 100. The modular circuit board 200 may further comprise an intermediary board (or central controller) 210 operable to facilitate communication between the plurality of modules 220 and with a network 205. Modular circuit board 200 may also comprise one or more connection points for connection to ethernet, fiber, power, and other such cable connections. Modules 220 may be interconnected to the intermediary board 210 through any desired bus protocol such as, but not limited to, ISA—Industry Standard Architecture, EISA—Extended Industry Standard Architecture, MCA—Micro Channel Architecture, VESA—Video Electronics Standards Association, PCI—Peripheral Component Interconnect—PCI, PCI Express (PCIe, PCI-e or PCI-X), PCMCIA—Personal Computer Memory Card Industry Association (also called “PC” bus), AGP—Accelerated Graphics Port, SCSI—Small Computer Systems Interface, Versa Module European—VME, IEEE 1394 Firewire, Lightning bus protocol, and in a preferred embodiment, comprises a PCI-e bus connection protocol.

Reference is now made to FIG. 5, which depicts block diagrams of components comprising the intermediary board 210 and exemplary modules of the plurality of modules 220 of the modular circuit board 200 of FIG. 4. The plurality of modules 220 may comprise, for example, one or more radio module 230, small cell module 240, security module 250, data analytics module 260, point-to-point/multipoint module 270, and VPN module 280. However, one of skill in the relevant arts can appreciate how the modular architecture may accommodate additional functions or features beyond those listed, and in more or less number than those illustrated.

Intermediary board (or central controller) 210 may facilitate the processing of information and distribution of work load across the plurality of modules 220, and may comprise a central processing unit 212 for processing information obtained from the plurality of modules 220, storage 214 for storing long-term data, memory 216 for storing short-term data, and a plurality of input/output nodes 218 for connection to the plurality of modules 220.

Next, the plurality of modules 220 may comprise, for example, one or more radio modules 230, as shown in FIGS. 5 and 6. The one or more radio modules 230 may be configured to provide Wi-Fi radio connectivity for the wireless access point 100. In an implementation, each radio module of the one or more radio modules 230 may be

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electrically coupled to a separate one of the one or more antenna **112**, **114**, **116** of the first antenna layer **110** and/or a separate one of the one or more antenna **122**, **124**, **126** of the second antenna layer **120** of the wireless access point **100**. In another implementation, and as shown in FIG. 6, a single radio module **230** may be electrically coupled to two or more antennas in one or more antenna layers. Based on a given number of users and the capacity of the wireless access point, any configuration of radio module **230** to antenna(s) may be accommodated according to the present disclosure. Radio module **230** may offer Wi-Fi 1-6 (formerly, A/B/G/N/AC/AX) coverage and may support a combination of wireless radio bands, including 2.4 GHz and 5 GHz bands, WPA/WPA2/WPA3 encryption, and mesh capabilities. Radio module **230** may comprise, for example, a central processing unit **232**, memory **234**, storage **236**, radio **238**, and input/output node **239**.

As shown in FIG. 5, the plurality of modules **220** may further comprise small cell module **240**. Small cell module **240** may provide cellular wide area network (WAN) connectivity to the wireless access point **100** and support cellular carrier offloading. The small cell module **240** may provide 3G, 4G, and 5G connectivity to the access point, without the need for additional infrastructure. Small cell module **240** may comprise, for example, a central processing unit **242**, memory **244**, storage **246**, cellular radio **248**, and input/output node **249**.

Security module **250** may add comprehensive security features such as intrusion detection systems (IDS) and intrusion protection systems (IPS). IDS and IPS may parse and interpret network data and host activities. Such data may range from network packet analysis to the contents of log files from routers, firewalls, servers, local system logs, access calls, and network flow data. Security module **250** may comprise, for example, a central processing unit **252**, memory **254**, storage **256**, and input/output nodes **258**. Two input/output nodes **258** may be used, operating as a pass-through so that one input/output node allows data traffic in and one input/output node allows data traffic out. This may allow for a more comprehensive analysis of data traffic and identification of vulnerabilities in the system. In other implementations, a single input/output node may also be employed.

Data analytics module **260** may collect data gathered by the wireless access point **100** and send the data to the management platform. The management platform (not shown) may be a server that is utilized for aggregation, processing, and detailed analysis of data gathered by the wireless access point **100**. The management platform may reside on a cloud may comprise a physical server stored in a data center. The data analytics module **260** may be used to improve network performance and offer users improved connectivity. Data analytics module **260** may comprise, for example, central processing units **262**, memory **264**, storage **266**, and input/output node **268**. At least two central processing units **262** are preferred, allowing for faster processing of gathered data.

Point-to-Point/Multipoint module **270** may offer point-to-point, point-to-multipoint, and multipoint-to-multipoint connectivity for long distances outside the range of mesh capabilities. The operating frequencies may encompass the 900 MHz, 2.4 GHz, 3.65 GHz, and 5 GHz ranges or additional radio frequencies as they are approved for utilization. Point-to-Point/Multipoint module **270** may comprise, for example, a central processing unit **272**, memory **274**, storage **276**, radio **278**, and input/output node **279**.

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VPN Module **280** may provide secure, encrypted connectivity on a per-client basis and may allow the wireless access point **100** to support a large volume of encrypted connections. This type of connectivity may be preferred in environments with specific compliance requirements. VPN Module **280** may comprise, for example, a central processing unit **282**, memory **284**, storage **286**, and input/output node **288**.

Although the modular circuit board **200** is described above in conjunction with specific modules (each having specific functionality), it is to be understood that the modular circuit board of the present disclosure may comprise any number of modules having any functionality desired and/or relevant in the art. The number and types of modules on the modular circuit board may be limited only by physical constraints such as limitations on power and bus structures. Additionally, while modular circuit board **200** and modules **220-280** are described above in conjunction with wireless access point **100**, it is to be understood that the modular circuit board of the present disclosure may be configured to operate in various applications, for various purposes, and in various systems, particularly in cellular applications and other such telecommunications systems.

Reference is now made to FIG. 7, which depicts an exploded view of housing **300** for enclosing a wireless access point **100** according to the present disclosure. Housing **300** may comprise a bottom member **310**, which may generally have a bowl-like shape, a top member **320** configured to be coupled to the bottom member **310**, and a lid **350** for closing the top of housing **300**. Top member **320** may comprise an external threaded ridge **330** configured to matably couple with a corresponding internal threaded portion (not shown) in bottom member **310**. Once wireless access point **100** is positioned and secured within housing **300**, top member **320** may be secured to bottom member **310**. The top member **320** may couple to bottom member **310** such that housing **300** may close in a manner similar to the closing of a lid to a jar. Top member **320** may further comprise an external threaded neck **340** for matably engaging internal threading (not shown) of lid **350**. The top surface of lid **350** may further be coupled to conduit **360**, a hollow pipe-like connector for connecting to support column **510** (shown in FIG. 10).

Reference is now made to FIG. 8, which depicts a perspective view of partially assembled housing **300**, and to FIGS. 9A and 9B, which depict plan and perspective views, respectively, of a cable mount system **400**. As shown in FIG. 8, the inside portion of the neck **340** of the top member **320** of housing **300** may comprise one or more cable holes **342**, **344**, **346**, **348**. Each cable hole **342**, **344**, **346**, **348** may be configured to receive one cable mount system **400** (shown in FIGS. 9A and 9B). A cable mount system **400** may comprise a cable **410**, a mount **420**, a cable covering **430**, and a coupler **440**. Cable **410** may comprise ethernet, fiber, power, or other such cable that may be connected to the electronic circuit board **160** of the wireless access point **100**. A cable **410** may mount to a cable hole **342**, **344**, **346**, or **348** on housing **300** via cable mount **420**, which may be threaded into a cable hole **342**, **344**, **346**, **348**. Coupler **440** of the cable mount system may be inserted through a cable hole **342**, **344**, **346**, **348** and into housing **300**, where it may be connected to components of the electronic circuit board **160** (of FIG. 1). Cable covering **430** may be disposed over mount **420** and may serve as an impermeable seal to ensure protection of the interior of the housing (including the wireless access point **100**) from liquid, particles, or other matter. As shown in FIG. 8, four cables may be mounted to

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the four cable holes **342**, **344**, **346**, **348** via mounts. Although four cable holes are shown in FIG. **8**, the present disclosure is not limited to any particular number of cable holes or corresponding cable mount systems. The mounted cables may be gathered into a single bundle and fed through conduit **360** for connection to a power/control system within support column **510** (FIG. **10**).

Reference is now made to FIG. **10**, which depicts a wireless access point assembly **500** according to the present disclosure. Cables mounted to the cable holes **342**, **344**, **346**, **348** (FIG. **8**) run through conduit **360** for connection to a power and control center housed within support column **510**. Support column **510** may resemble a lamp post or other street fixture that may blend into a cityscape. As such, the wireless access point assembly **500** of the present disclosure may be used in connection with smart cities, stadiums, aviation centers, and other highly populated centers where public Wi-Fi connectivity is desired.

With further reference to the previously-described figures, an implementation of a method of configuring a wireless access point according to the present disclosure may comprise: mounting a first set of antennas operating at a first wireless radio band in a first layer around a support structure; and mounting a second set of antennas operating at a second wireless radio band in a second layer around the support structure, wherein the first layer and the second layer form a stacked configuration. The method may further comprise dividing at least one of said first layer and second layer into sectors, wherein if said first layer is divided into sectors, each antenna of said first set of antennas is assigned to a different sector; and wherein if said second layer is divided into sectors, each antenna of said second set of antennas is assigned to a different sector. Incorporating by reference the foregoing paragraphs of the disclosure, the method may further comprise any or all of the steps described above with the respect to the wireless access point **100**.

FIG. **11** depicts an embodiment of the present invention showing a housing **600** that includes a top member **600** including a collar **640** with one or more housing fasteners **641**, and a connection flange **625** with one or more fasteners **626** engaging with a flange support member **627** that is mechanically coupled to the bottom member **610**. The bottom member **610**, as also shown in FIGS. **12**, **16**, **17**, **18**, and **19**, is configured to at least partially cover antenna elements disposed within the communications module **700**, and as such, may act as a radome to provide mechanical and environmental protection for such antenna elements. Further, the bottom member **610** may comprise any suitable dielectric-controlled material such as KYDEX® to reduce attenuation of RF signals transmitted from or received by such antenna elements. Radome material may be integrated into the bottom member **610** through molding, stretching a flexible sheet above a frame, or any other desired approach, and may be designed as an electrically thin dielectric layer, a half-wave thick radome, a foam-core laminate, a C-Sandwich laminate, or any other configuration designed to minimize attenuation and optimize performance of the installed antennae elements. Housing fastener **641** secures the housing **600** through collar **640** to an external fixture, which may include but is not limited to a light pole, a conduit, a factory equipment interface, a network controller, a fixture on a farm equipment, a building fixture interface, a buoy interface, a ship or aircraft interface, a vehicle interface, and the like. Fastener **641** may comprise any desired type of fastener such as a set screw, a bolt, a machine screw, a rivet, or a pin for engaging in a bayonet-type interface, wherein the collar is

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on the inside of a larger fixture collar with keyed slots therein). Likewise, fastener **626** may comprise any desired type of fastener such as a set screw, a bolt, a machine screw, a rivet, or a pin for engaging in a bayonet-type interface. In one embodiment, not illustrated, the fasteners **626** engage within keyhole-type openings within the flange support member **626** so that the bottom member **610** may be rotated with respect to the top member **620**, aligning clearing openings in the flange support member **627** with fasteners **626**, and as such, the bottom member **610** may be removed by moving the bottom member **610** away from the top member **620** after rotation. When the housing **600** is installed in its intended application, the collar **640** may be disposed substantially inside of an external fixture, or may surround and enclose part of the external fixture.

FIG. **12** shows a cutaway view of a communications module **700**, showing an opening in the housing **600**, an electronics section **710**, and an environmental component interface section **712**. In various embodiments, a horizontal partition **740** divides the housing **600** into an electronics section **710** and an environmental component interface section **712**, and may provide mechanical support for electronics components situated within the electronics section **710** of the housing **600**. A flange support member **627** is shown as mechanically coupled to the bottom member **610**. In various embodiments, the partition **740** may comprise a ground plane providing electrical and RF shielding between the electronics section **710** and the environmental component interface section **712**. Although illustrated with the electronics section **700** disposed in a top portion of the module **700** and the environmental component interface **712** disposed in a bottom portion of the module **700**, those of skill in the art appreciate alternative arrangements of the electronics section **710** and the environmental component interface **712** are possible, including, if desired, co-locating electronics components with various components of the environmental component interface section **712**.

FIG. **13** illustrates a top perspective view of the communications module **700**, with the top member **620** in semi-transparent rendering to illustrate one embodiment of an electronics section **710** of the communications module **700**. Further, FIG. **14** shows a similar top perspective view **1400** of a portion of communications module **700**, with the top member **620** completely removed. In the illustrated embodiments, on the partition **740**, an intermediary board or central controller **810** is disposed, which may comprise a number of components and configurations as illustrated in regards to element **201** in FIG. **5**, and is further shown with one or more removable module(s) **820** installed in a bus interface placing the module in electrical communication with the central controller **810**, one or more bus interface connectors such as PCI-E connectors **821**, shielding/supports **831**, power connector **862**, and power supply/regulator **835**. One or more modules **820** may vary in size, and the shielding/supports **831** may accommodate various sizes of modules such as the longer module **820a** in comparison to shorter modules **820**; further, the shielding/supports **831** may provide mechanical support for the modules **820** and offer registration slots or pins to ensure proper insertion of modules **820**, **820A** into connectors **821**. In FIG. **13**, the top member **620** is shown as transparent, and may be implemented with a transparent, semi-transparent, or opaque material depending on the intended use of the communications module **700**. A transparent rendering of the collar **640** and flange **625** are included in one exemplary arrangement as shown in FIG. **13**.

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FIG. 15 shows a bottom perspective view of an embodiment of the communications module 700 with the bottom housing removed. The antenna elements 812, 814, 822, and 824, are respectively disposed in a downward-facing orientation, as opposed to the upward-facing orientation shown for antenna elements 112, 114, 116, 122, 124, and 126 as shown in regards to FIGS. 1, 2, 3A, and 3B; in embodiment utilizing the downward-facing orientation, improved RF performance may result when the communications module 700 is mounted at a vertical height above the intended communication targets, such as when being mounted on a pole with persons carrying mobile devices disposed at a level below the communications module 700. In other embodiments, the antenna elements may be mounted in any desired orientation to optimize RF performance in the external environment in which the module 700 operates. Similar to the embodiments described in regards to FIGS. 1, 2, 3A, and 3B, antenna elements 812, 814, 822, and 824 are respectively installed in shielded sectors 813, 815, 823, and 824, and respectively attached to central support structure 830 through mounting structures 850. Further, antenna elements 812, 814, 822, and 824 are shown electrically coupled to coax bulkhead headers 855 that allow signals to pass through the partition 740 to allow electrical coupling to the central controller 810 and/or modules 820. In one embodiment, wiring from the antenna elements 812, 814, 822, and 824 may comprise coaxial cabling electrically coupling the antenna elements to the coax bulkhead headers 855. Correspondingly, (and as shown in FIG. 14) on an opposite side of the partition 740, the coax bulkhead headers 855 are electrically coupled to coaxial cables providing respective electrical connections between the coax bulkhead headers 855 and respective modules 820 and/or the central controller 810.

Similarly as discussed in regards to FIGS. 1, 2, 3A, and 3B, the antenna elements shown in FIG. 15 are arranged in two layers, with antenna elements 812, 814, in respective sectors 813, 815 are disposed within a first layer 875, and the antenna elements 822, 824, in respective shielded sectors 823, 825, are disposed within a second layer 876. Although the illustrated embodiment shows an arrangement with two layers having four sectors/antennas per layer attached to the central support structure 830, any number of desired antennas may be assigned to any particular layer, and any desired number of layers may be used in the communications module 700. Further additional components may be attached to the central support structure 830, and may include a wide variety of devices. For additional reference, FIG. 16 illustrates a side exploded view of an embodiment of the communications module 700, with reference numerals corresponding to elements described in regards to FIGS. 11-15.

FIG. 17 illustrates a side view of an embodiment of the communications module 900 of the present invention. Bottom member 610 may include a distal portion 610a, to which an accessory module 910 may be sealably attached. In one embodiment, distal portion 610A includes an opening through which mechanical and electrical connections to the accessory module 910 are completed, and such opening may be optionally mated to the accessory module through a gasket or seal to provide environmental protection of the interior components. Accessory module 910 may include any number of components as desired, such as a fixed camera, a remotely controllable camera (such as a remotely rotatable and zoomable camera), one or more laser transmitters/receivers/transceivers; an infrared module; a smoke detector; a carbon dioxide detector; a carbon monoxide detector; an ozone detector; a particulate detector; a micro-

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phone; a speaker; a laser transmitter/receiver/transceiver; an optical communications module; a seismic sensor; a pollution sensing module; a gunshot detector; a lighting apparatus; a weather sensor; an avalanche detector; a tornado warning detector, a wind speed and direction sensor; a traffic sensor; a wireless charging transmitter/receiver/transceiver. Although the aforementioned devices are described as being included within the accessory module 900, those of skill in the relevant arts understand that such components may be disposed anywhere within the communications module 900. Cameras disposed within the accessory module 910 may be of the still frame capture variety or may be video cameras or may provide either function as desired. Such cameras may be equipped, for example, to scan QR codes presented in proximity to the communications module, track and remotely transmit images or video data regarding a condition in proximity to the communication module, or to obtain image data to support human facial recognition or crowd flow information. In instances where cameras are situated within the accessory module 910, the outer housing of the accessory module 910 may be transparent, or at least partially transparent, and may be tinted as illustrated to at least partially conceal cameras located within accessory module. Components within the accessory module may be in electrical communication with the central controller 810, such as through a wired connection that extends between the components and the controller 810 through an interior space of the support structure 830, or around an outside surface of the support structure 830.

FIG. 18 illustrates a side exploded view of the communications module 900 that was illustrated in FIG. 17. Two antenna layers 875, 876 are shown as situated between the top member 620 and the bottom member 610, and the accessory module 910 is shown with a support structure extension 830A, which, when installed, extends through distal portion 610A of the bottom member 610 to interface with the support structure 830. As shown, the support structure extension 830A also includes a flanged portion 830b which is configured to engage within the support structure 830 to allow registration of the support structure extension 830A with the support structure 830. In one embodiment, when accessory module 910 is attached to bottom member 610, the bottom member 610 and accessory module 910 may be removed from the communications module system 900 as a unit. In an alternative embodiment, communications module 910 is a fixed to the central support 830 through the support extension 830B, 830B and is configured to allow the bottom member 610 to be removed over the accessory module 910 while the accessory module 910 still remains attached to the support structure 830. In such a circumstance, a gasket may be disposed within the bottom member 610 to provide for environmental sealing between the bottom member 610 and accessory module 910 and is configured to allow the bottom member 610 to be slidably removed over the accessory module 910.

FIG. 19 illustrates a side exploded view of a communications module 1000 of the present invention. In the illustrated embodiment, environmental component interface section 712 includes four layers of antennas 875, 876, 875A, and 876A. Before antenna layers are shown disposed around and attached to support structure 830. As can be appreciated by those of skill in the relevant arts, any number of antenna layers may be included within the communications system 1000, and the system may be configured as desired for the intended implementation. Furthermore one or more horizontal RF shielding plates or ground planes, such as a metallic disc (not shown) may be interposed between any of the

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antenna layers to reduce crosstalk and optimize RF performance of the respective antenna layers. Although antenna layers **875**, **876**, **875A**, and **876A** are shown with fixed directional antenna elements, in alternative embodiments, each layer may be locally or remotely tunable by adjusting orientation of the antenna elements and/or through electronic beam-forming approaches, or a combination of both approaches. In addition, although antenna layers **875**, **876**, **875A**, and **876A** are shown installed and in proximity to one another, in one embodiment, as depicted further in regard to FIG. **20**, the layers may be individually removable, improving maintainability and upgradability by reducing the need to completely disassemble the communications module **1000**. In one aspect, individual antenna elements may also be individually interchangeable through a socketed connection within the layer; in this embodiment and others, an antenna layer may comprise a diversity of antenna elements operating in different frequency bands as desired to support the intended operational environment of the communications module. In certain embodiments a cylindrical housing extension (not shown) with an interior diameter approximating that of the top member **620** and bottom member **610** may be inserted between the top member **620** and the bottom member **610** to provide environmental protection for the extended antenna array layers shown in the environmental component interface section **712**. Further, in various embodiments, the extension may be an integral part of the top member **620** or the bottom member **610** depending on details of the particular implementation.

In various embodiments, communications module **1000** may operate cellular small cell antennas, radio units, and baseband interfaces to support local small cell implementations through the communications module **1000**. One or more antennae may be integrated within the top member **620** or bottom member **610** of the communications module **1000**, such as millimeter-wave patch antenna, an array of dual-polarized antenna elements, a phased array antenna, and the like. In one alternative embodiment, the members **610** and/or **620** may be rotated on the unit about the central support structure **830** to tune or point integrated antennae in a desired direction to achieve optimal RF performance; in one case, in an implementation of a massive MIMO (multiple-input, multiple-output) array, an included cellular base station comprising of a plurality of antennas may be optimized for bandwidth performance by rotating elements of the top member **620** or bottom member **610** with respect to the installed environment.

The bottom member **610** or top member **620** may comprise an additional antenna elements (such as **610B** **620A**) mounted within, inside, outside of the housing. In certain embodiments, mounting one or more antenna elements within or outside the radome may result in improved RF performance, particularly in millimeter-wave applications such as 5G telephony. Antenna elements **610B**, **620A** may be electrically coupled to the central controller **810** to allow transmission of signals and/or power to the antenna elements **610B**, **620A**.

FIGS. **20** through **24C** depict various embodiments for interchangeable antenna layers. FIG. **20** shows a side view of an antenna layer **875**, and its corresponding top profile view depicted as an approximate circle in FIG. **21** with a cross-sectional view of the support structure **830** situated within the antenna layer **875**. In one embodiment, antenna layer **875** may be slid onto the support structure **830** as a single unit, and affixed thereto using any desired fastening technique. In alternative embodiments, it may be desirable to install an entire antenna layer without needing to remove

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adjacent antenna layers from the support structure **830**. In such an instance, antenna layers may be configured to have openable portion to allow installation and removal from the central support structure **830**. Although in FIGS. **20** through **24**, and in other figures described above, the central support structure is approximately square in cross-section, any desired shape may be utilized to achieve any desired purpose, and circular, elliptical, triangular, polygonal, or any desired cross-section may be utilized for the support structure **830**, and different cross-sections may be utilized in concert with different antenna layers to support dimensional changes antenna elements.

In FIGS. **22A** through **22D**, top views of antenna layer profile **877** include a movable portion **879**, hingedly connected **878** to a C-Shaped second section **880** of the antenna layer **877**. A fastener such as a locking clamp, not shown, may be used to secure the movable portion **879** to the second section **880**. The central support structure **830** is shown in cross section in the center of the antenna layer **877**. FIGS. **22B** and **22C** show the movable section **879** being opened hingedly in an outward direction (after any fasteners were released), exposing the central support structure **830** and creating a void to allow removal of the antenna layer **877**. FIG. **22D** shows the antenna layer **877** then being moved **881** to allow removal of the antenna layer **877** from the central support structure **830**. Installation of such an antenna layer **877** may be accomplished in the reverse order.

In FIGS. **23A** through **23D**, top plan views of antenna layer profile **977** include a movable portion **979**, removably connected to a second C-Shaped section **980** of the antenna layer **977**. One or more fasteners such as locking clamps, not shown, may be used to secure the movable portion **979** to the second section **980**. The central support structure **830** is shown in cross section in the center of the antenna layer **977**. FIGS. **23B** and **23C** show the movable section **979** being removed in an outward direction (after any fasteners were released), exposing the central support structure **830** and creating a void to allow removal of the antenna layer **977**. FIG. **23D** shows the antenna layer **977** then being moved **981** to allow removal of the antenna layer **977** from the central support structure **830**. Installation of such an antenna layer **977** may be accomplished in the reverse order.

In FIGS. **24A** through **24D**, top plan views of antenna layer profile **997** include movable sections **999** and **990** of the antenna layer **997**. One or more fasteners such as locking clamps, not shown, may be used to secure the movable sections **999** and **990** together. The central support structure **830** is shown in cross section in the center of the antenna layer **997**. FIGS. **24B** and **24C** show the sections **999** and **990** being removed in an outward direction (after any fasteners were released), exposing the central support structure **830** and allowing removal of the antenna layer **997** from the central support structure **830**. Installation of such an antenna layer **997** may be accomplished in the reverse order.

Those of skill in the relevant arts appreciate that various combinations of components and configurations described herein comprise additional embodiments of the claimed invention. Examples of additional inventive combinations include the following:

1. A configurable communications module comprising:
 - a plurality of antenna elements organized into a plurality of layers, each antenna element independently accessible and interchangeable within the communications module;
 - a central support structure providing mechanical support for the plurality of layers;

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- a central controller module in electrical communication with the plurality of antenna elements; and wherein the antenna elements within a layer of the plurality of layers operate within one assigned frequency band; each layer of the plurality of layers includes a shielding element to reduce interference; and each respective antenna element is respectively accessible for maintenance and replacement.
2. The configurable communications module of claim 1 wherein the communications module further comprises a housing, wherein at least a portion of the exterior of the housing comprises environmentally protected and electrically transmissive material.
 3. The configurable communications module of claim 2 wherein the communications module is partitioned into an electronics section and an environmental component interface section.
 4. The configurable communications module of claim 3 wherein:
 - a partition is disposed between the electronics section and the environmental component interface section;
 - the partition is configured to provide RF shielding between the electronics section and the environmental component interface section; and
 - the partition includes electrical headers to allow electrical interconnect between modules disposed within the electronics section and components disposed within the environmental interface section.
 5. The configurable communications module of claim 2 or claim 3 or claim 4 wherein the housing is removable to access and maintain at least one of the plurality of antenna elements and the central controller module.
 6. The configurable communications module of claim 1 or claim 2 wherein the antenna elements are in electrical communication with the central controller through a plurality of cables passing within the central support structure.
 7. The configurable communications module of claim 1 wherein the antenna elements in at least one of the layers operate within a 2.4 GHz wireless radio band.
 8. The configurable communications module of claim 1 wherein the antenna elements in at least one of the layers operate within a 5 GHz wireless radio band.
 9. The configurable communications module of claim 1 wherein the antenna elements in at least one of the layers operate within a cellular telephony band.
 10. The configurable communications module of claim 1 wherein the antenna elements in at least one of the layers operate within a 5G cellular telephony band.
 11. The configurable communications module of claim 1 or claim 7 or claim 8 or claim 9 or claim 10 wherein the antenna elements in at least one of the layers are configured operate within one of an AMPS, GSM, 3G, 4G, or LTE cellular telephony band.
 12. The configurable communications module of claim 1 or claim 11 wherein each respective layer is configured to be installed on or removed from the central support structure as a unit.
 13. The configurable communications module of claim 1 or claim 12 wherein each respective layer may be independently removed from or installed within the communications module without removing other layers within the communications module.
 14. The configurable communications module of claim 1 or claim 11 wherein a layer of antenna elements includes a

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- plurality of directional antenna elements oriented in respectively different directions.
15. The configurable communications module of claim 1 or claim 13 wherein each respective layer comprises a C-Shaped layout with a hinged closure.
 16. The configurable communications module of claim 1 wherein the central controller module comprises a plurality of radio modules respectively electrically connected to the plurality of antenna elements.
 17. The configurable communications module of claim 16 wherein the radio modules may be interchanged without replacing the central controller module.
 18. The configurable communications module of claim 1 or claim 16 or claim 17 further including an interface from the antenna elements to an external communications network.
 19. The configurable communications module of claim 18 wherein a connection to the external communication network is implemented via one or more of a fiber-based connection, a wired connection, and optical connection a cellular backhaul connection or a microwave link.
 20. The configurable communications module of claim 1 or claim 11, further comprising one of a Bluetooth transceiver and an RFID transceiver.
 21. The configurable communications module of Claim 1, further comprising one or more of: a fixed camera, a remotely controllable camera, one or more laser transmitters; one or more laser receivers; one or more laser transceivers; an infrared module; a smoke detector; a carbon dioxide detector; a carbon monoxide detector; an ozone detector; a particulate detector; a microphone; a speaker; an optical communications module; a seismic sensor; a pollution sensing module; a gunshot detector; a lighting apparatus; a weather sensor; an avalanche detector; a cellular repeater; a point-of-sale (POS) terminal; a tornado warning detector, a wind speed and direction sensor; a traffic sensor; a wireless charging transmitter/receiver/transceiver; and a battery.
 22. The configurable communications module of claim 1 or claim 11, wherein the antenna elements may comprise a plurality of band transmission cores providing operation within a plurality of operating frequencies.
 23. The configurable communications module of claim 1 or claim 11 or claim 22, further comprising an omnidirectional antenna element.
 24. The configurable communications module of claim 23, wherein the central controller module is disposed at a first end of the support structure, and the omnidirectional antenna element is disposed at an opposite end of the support structure.
 25. The configurable communications module of claim 1 or claim 5 or claim 11, wherein a bottom portion of the support structure further includes a 5G cellular antenna element.
 26. The configurable communications module of claim 1 or claim 5 or claim 11, wherein the central support structure may be extended by one of: telescoping an internal extension element and mechanically mating an extension thereto.
 27. The configurable communications module of claim 1 or claim 21, wherein the module is configured to operate within one of: an urban environment; a rural environment; a building; an airport; a farm; a factory; and a recreation area.
 28. The configurable communications module of claim 1 or claim 21 or claim 27 or claim 28, further comprising a solar panel interface.

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29. The configurable communications module of claim 1, wherein the communications module is further configured to monitor one or more of a soil composition; crop health; animal location; animal health; watering and/or irrigation moisture; oil well pressure; oil well flow; stadium human movement and traffic; security conditions using human facial recognition; pollution emissions; vehicular traffic flow; a weather condition in proximity to the communications module; a safety-related condition; a crime event; a fire event; and combinations thereof.
30. The configurable communications module of claim 29, wherein further comprising a radome.
31. The configurable communications module of claim 30, wherein the radome is configured to include an electrically thin dielectric layer, a half-wave thick layer, a foam-core laminate layer, a C-sandwich laminate layer, or a combination thereof.
32. The configurable communications module of claim 1 or claim 21, wherein the communications module is further configured to process one of: point-of-sale (POS) transactions; orders for a product or service to be delivered to a person's assigned seat; instructions to guide a person to a designated location; a person's ticket idicia to grant or deny access to a venue; data obtained from a scan of a QR code displayed by a person in proximity to the communications module; interactive advertising to a person in proximity to an interactive signage; reservation requests for use of a facility; data for use in augmented reality presented on a mobile device; and combinations thereof.
33. The configurable communications module of claim 1 or claim 11, wherein each antenna element may be interchanged through a socketed connection.
34. The configurable communications module of Claim 1, wherein the antenna elements within a layer of the plurality of layers operate within a plurality of assigned frequency bands.

It is to be understood the implementations are not limited to particular systems or processes described which may, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular implementations only, and is not intended to be limiting. As used in this specification, the singular forms "a", "an" and "the" include plural referents unless the content clearly indicates otherwise.

Although the present disclosure has been described in detail, it should be understood that various changes, substitutions and alterations may be made herein without departing from the spirit and scope of the disclosure as defined by the appended claims. Moreover, the scope of the present application is not intended to be limited to the particular embodiments of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure, processes, machines, manufacture, compositions of matter, means, methods, or steps, presently existing or later to be developed that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized according to the present disclosure. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.

The particular implementations shown and described above are illustrative of the invention and its best mode and are not intended to otherwise limit the scope of the present invention in any way. Indeed, for the sake of brevity, conventional data storage, data transmission, and other

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functional aspects of the systems may not be described in detail. Methods illustrated in the various figures may include more, fewer, or other steps. Additionally, steps may be performed in any suitable order without departing from the scope of the invention. Furthermore, the connecting lines shown in the various figures are intended to represent exemplary functional relationships and/or physical couplings between the various elements. Many alternative or additional functional relationships or physical connections may be present in a practical system.

Changes and modifications may be made to the disclosed embodiments without departing from the scope of the present invention. These and other changes or modifications are intended to be included within the scope of the present invention, as expressed in the following claims.

What is claimed is:

1. A configurable communications module comprising:
 - a plurality of antenna elements organized into a plurality of layers, each antenna element independently accessible and interchangeable within the communications module;
 - a central support structure providing mechanical support for the plurality of layers; and
 - a central controller module in electrical communication with the plurality of antenna elements;
 wherein

the antenna elements within a layer of the plurality of layers operate within one assigned frequency band; each layer of the plurality of layers includes a shielding element to reduce interference; and each respective antenna element is respectively accessible for maintenance and replacement,

wherein the communications module further comprises a housing, wherein at least a portion of the exterior of the housing comprises environmentally protected and electrically transmissive material,

wherein the communications module is partitioned into an electronics section and an environmental component interface section,

wherein:

a partition is disposed between the electronics section and the environmental component interface section; the partition is configured to provide RF shielding between the electronics section and the environmental component interface section; and the partition includes electrical headers to allow electrical interconnect between modules disposed within the electronics section and components disposed within the environmental interface section.

2. The configurable communications module of claim 1 wherein the housing is removable to access and maintain at least one of the plurality of antenna elements and the central controller module.

3. The configurable communications module of claim 1 wherein the antenna elements are in electrical communication with the central controller through a plurality of cables passing within the central support structure.

4. The configurable communications module of claim 1 wherein the antenna elements in at least one of the layers operate within a 2.4 GHz wireless radio band.

5. The configurable communications module of claim 1 wherein the antenna elements in at least one of the layers operate within a 5 GHz wireless radio band.

6. The configurable communications module of claim 1 wherein the antenna elements in at least one of the layers operate within a cellular telephony band.

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7. The configurable communications module of claim 1 wherein the antenna elements in at least one of the layers operate within a 5G cellular telephony band.

8. The configurable communications module of claim 1 wherein the antenna elements in at least one of the layers are configured operate within one of an AMPS, GSM, 3G, 4G, or LTE cellular telephony band.

9. The configurable communications module of claim 1 wherein each respective layer is configured to be installed on or removed from the central support structure as a unit.

10. The configurable communications module of claim 1 wherein each respective layer may be independently removed from or installed within the communications module without removing other layers within the communications module.

11. The configurable communications module of claim 1 wherein a layer of antenna elements includes a plurality of directional antenna elements oriented in respectively different directions.

12. The configurable communications module of claim 1 wherein each respective layer comprises a C-Shaped layout with a hinged closure.

13. The configurable communications module of claim 1 wherein the central controller module comprises a plurality of radio modules respectively electrically connected to the plurality of antenna elements.

14. The configurable communications module of claim 13 wherein the radio modules may be interchanged without replacing the central controller module.

15. The configurable communications module of claim 1 further including an interface from the antenna elements to an external communications network.

16. The configurable communications module of claim 15 wherein a connection to the external communication network is implemented via one or more of a fiber-based connection, a wired connection, and optical connection a cellular backhaul connection or a microwave link.

17. The configurable communications module of claim 1, further comprising one of a Bluetooth transceiver and an RFID transceiver.

18. The configurable communications module of claim 1, further comprising one or more of: a fixed camera, a remotely controllable camera, one or more laser transmitters; one or more laser receivers; one or more laser transceivers; an infrared module; a smoke detector; a carbon dioxide detector; a carbon monoxide detector; an ozone detector; a particulate detector; a microphone; a speaker; an optical communications module; a seismic sensor; a pollution sensing module; a gunshot detector; a lighting apparatus; a weather sensor; an avalanche detector; a cellular repeater; a point-of-sale (POS) terminal; a tornado warning detector; a wind speed and direction sensor; a traffic sensor; a wireless charging transmitter/receiver/transceiver; and a battery.

19. The configurable communications module of claim 1, wherein the antenna elements may comprise a plurality of band transmission cores providing operation within a plurality of operating frequencies.

20. The configurable communications module of claim 1, further comprising an omnidirectional antenna element.

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21. The configurable communications module of claim 20, wherein the central controller module is disposed at a first end of the support structure, and the omnidirectional antenna element is disposed at an opposite end of the support structure.

22. The configurable communications module of claim 1, wherein a bottom portion of the support structure further includes a 5G cellular antenna element.

23. The configurable communications module of claim 1, wherein the central support structure may be extended by one of: telescoping an internal extension element and mechanically mating an extension thereto.

24. The configurable communications module of claim 1, wherein the module is configured to operate within one of: an urban environment; a rural environment; a building; an airport; a farm; a factory; and a recreation area.

25. The configurable communications module of claim 1, further comprising a solar panel interface.

26. The configurable communications module of claim 1, wherein the communications module is further configured to monitor one or more of a soil composition; crop health; animal location; animal health; watering and/or irrigation moisture; oil well pressure; oil well flow; stadium human movement and traffic; security conditions using human facial recognition; pollution emissions; vehicular traffic flow; a weather condition in proximity to the communications module; a safety-related condition; a crime event; a fire event; and combinations thereof.

27. The configurable communications module of claim 26 wherein further comprising a radome.

28. The configurable communications module of claim 27, wherein the radome is configured to include an electrically thin dielectric layer, a half-wave thick layer, a foam-core laminate layer, a C-sandwich laminate layer, or a combination thereof.

29. The configurable communications module of claim 1, wherein the communications module is further configured to process one of: point-of-sale (POS) transactions; orders for a product or service to be delivered to a person's assigned seat; instructions to guide a person to a designated location; a person's ticket indicia to grant or deny access to a venue; data obtained from a scan of a QR code displayed by a person in proximity to the communications module; interactive advertising to a person in proximity to an interactive signage; reservation requests for use of a facility; data for use in augmented reality presented on a mobile device; and combinations thereof.

30. The configurable communications module of claim 1, wherein each antenna element may be interchanged through a socketed connection.

31. The configurable communications module of claim 1, wherein the antenna elements within a layer of the plurality of layers operate within a plurality of assigned frequency bands.

32. The configurable communication module of claim 1, wherein the partition is further configured to provide mechanical support for the modules disposed within the electronics section.

33. The configurable communication module of claim 1, wherein the central controller is disposed on the partition.

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